

NASA Contractor Report 191034

1N-71
165069
P.176

User's Manual for UCAP:
Unified Counter-rotation Aero-acoustics Program

E. M. Culver, C. J. McCollgan
United Technologies Corporation
Hamilton Standard Division
Windsor Locks, Connecticut

April 1993

Prepared for
Lewis Research Center
Under Contract Number NAS3-24222



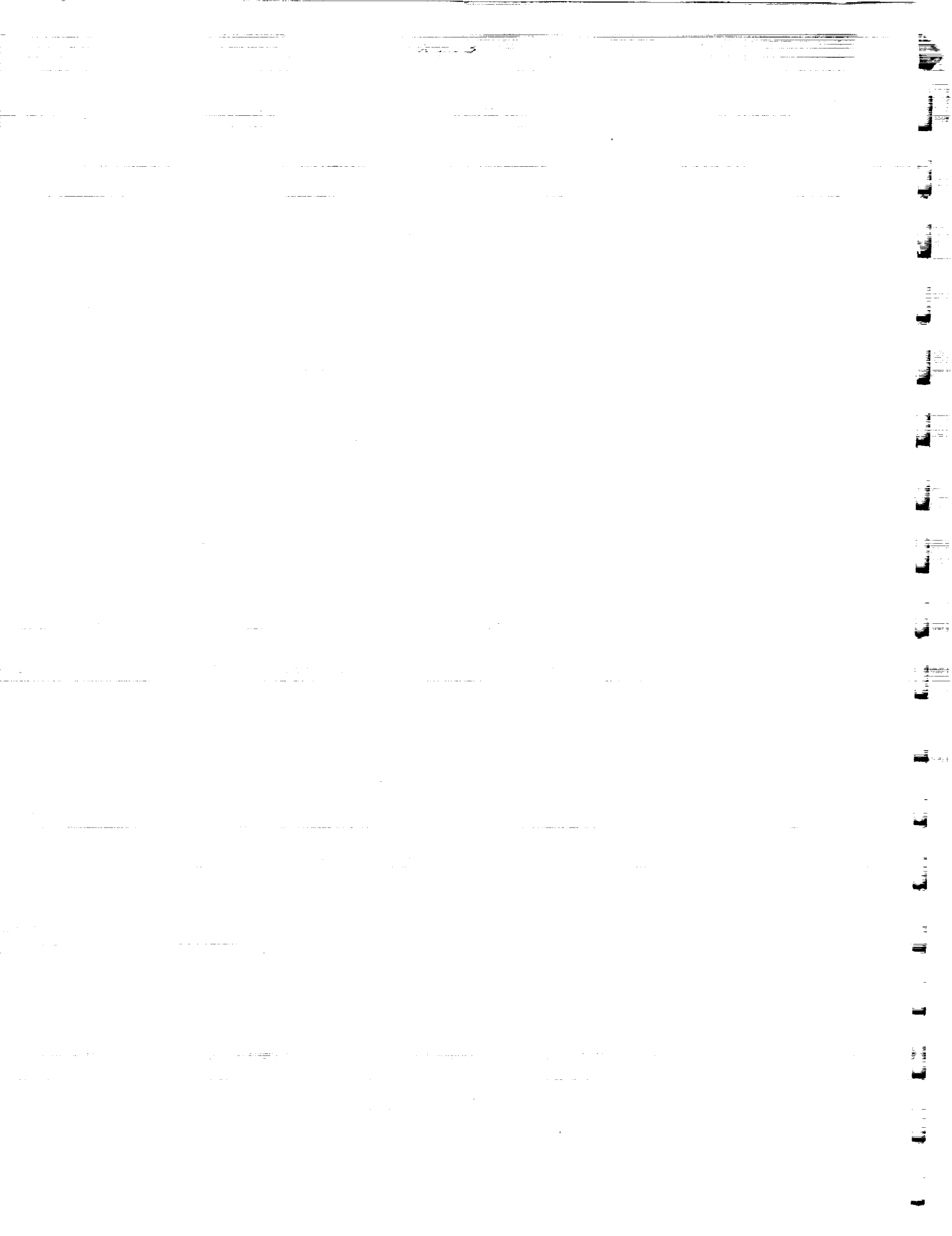
National Aeronautics and
Space Administration

(NASA-CR-191034 USER'S MANUAL FOR
UCAP: UNIFIED COUNTER-ROTATION
AERO-ACOUSTICS PROGRAM Final Report
(United Technologies Corp.) 176 p

N93-27148

Unclas

G3/71 0165069



NASA Contractor Report- 191034

User's Manual for UCAP: Unified Counter-rotation Aero-acoustics Program

E. M. Culver, C. J. McColgan
United Technologies Corporation
Hamilton Standard Division
Windsor Locks, Connecticut

April 1993

Prepared for
Lewis Research Center
Under Contract Number NAS3-24222



National Aeronautics and
Space Administration

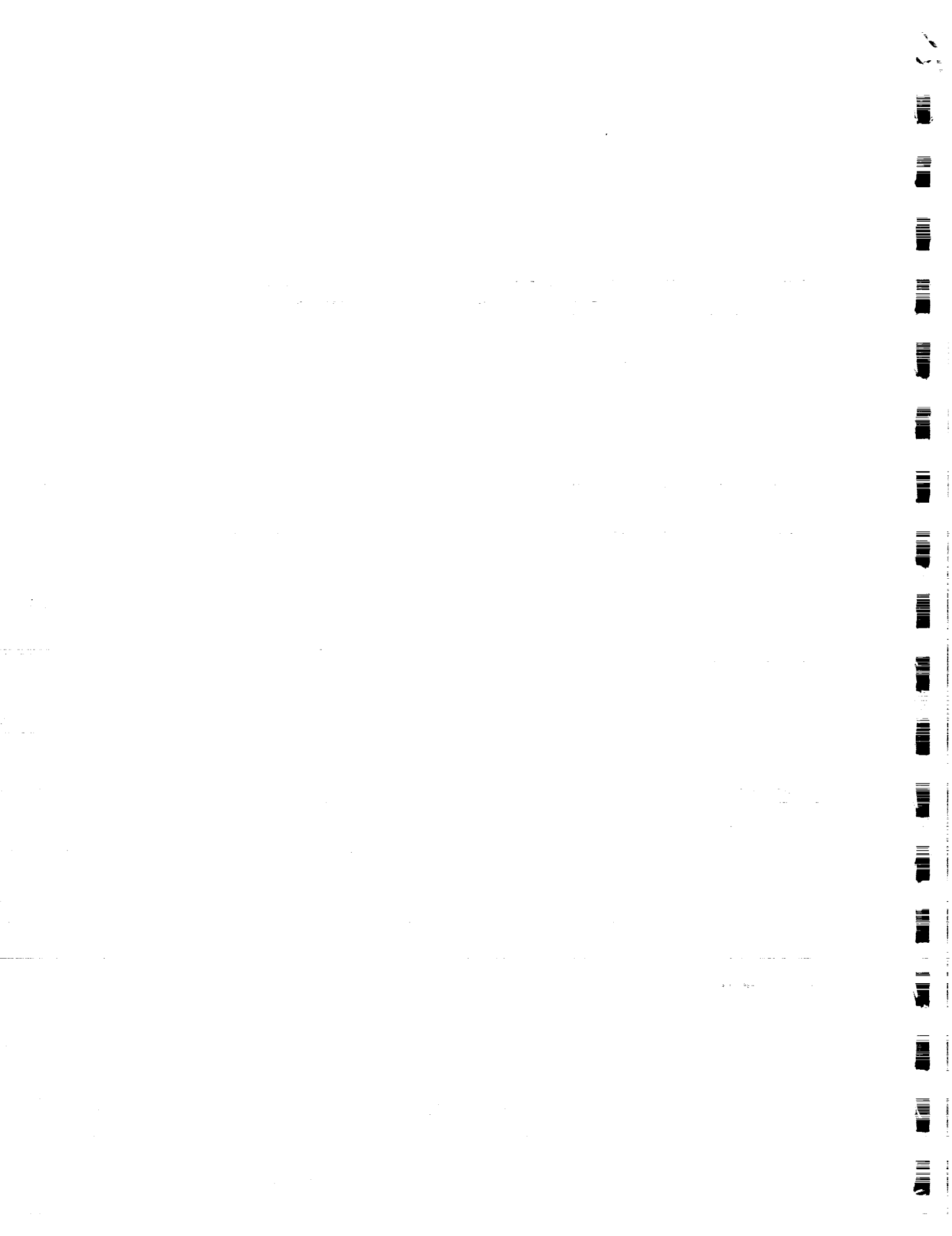


Table of Contents

	List of Figures	iv
	Summary	1
I.	Introduction	2
II.	Theory	4
III.	Program Organization	6
IV.	Input Description	8
	Commands	9
	Load	9
	Command Summary	10
	Specific Input Description	11
V.	Output Description	44
VI.	Noise Outputs	56
VII.	Program Installation	58
VIII.	File Requirements	59
IX.	Error Messages	62
	References	66
	Appendices	
A.	Example QWMU Generating Program and Modified Block Data CRPBLK	67

List of Figures

	<u>Page No.</u>
Figure 1 (part a)	Forward Rotor Velocity Diagram 77
Figure 1 (part b)	Rear Rotor Velocity Diagram 78
Figure 2	Conceptual Flow Chart of UCAP 79
Figure 3 (part a)	UCAP Calling Tree 80
Figure 3 (part b)	UCAP Subroutine Cross Reference Listing 93
Figure 3 (part c)	UCAP Subroutine Reference & Purpose Listing 96
Figure 3 (part d)	UCAP Labeled Common Area Reference Listing 100
Figure 4	Spanwise load panels and control points 102
Figure 5	Blade geometry nomenclature (2-D coords) 103
Figure 6	Blade geometry nomenclature (2-D coords) 104
Figure 7	Blade geometry nomenclature (RXY coord) 105
Figure 8	Blade geometry nomenclature (RXY coord) 106
Figure 9	Blade geometry nomenclature (RXY coord) 107
Figure 10	Blade geometry nomenclature (XYZ coord) 108
Figure 11	Input echo 109
Figure 12	RUNPARMS output 111
Figure 13	CRPPARMS output 112
Figure 14	AIRPARMS output 113
Figure 15	BLADEGEO output (2-DCOFWD: 2-D coordinates, forward rotor) 114
Figure 16	LSTPARMS output 115
Figure 17	NOIZPARM output 116
Figure 18	VELGRADS output 117
Figure 19	VORTPARM output 120
Figure 20	WAKEPARM output 121
Figure 21	INTERPRM output 122
Figure 22	AEROEXEC output (GETXMB section 1) 123
Figure 23	AEROEXEC output (GETXMB section 2) 124
Figure 24	Cylindrical "cutting" surface for blade section definition and for definition of advance coordinate, γ 125
Figure 25	AEROEXEC output (GETXMB section 3) 126
Figure 26	AEROEXEC output (GETXMB section 4) 128
Figure 27	AEROEXEC output (GETXMB section 5, LESWP output) 129
Figure 28	AEROEXEC output (GETXMB section 7) 130
Figure 29 (part a)	AEROEXEC output (CPMAP, front rotor) 131
Figure 29 (part b)	AEROEXEC output (CPMAP, rear rotor) 132
Figure 30	AEROEXEC output (lifting surface solver) 133
Figure 31	AEROEXEC output (1st camber table) 134
Figure 32	AEROEXEC output (ANS0) 136
Figure 33	AEROEXEC output (individual rotor performance summary) 138
Figure 34	AEROEXEC output (vortex calculations: operating conditions) 139
Figure 35	AEROEXEC output (vortex calculations: elemental data) 140

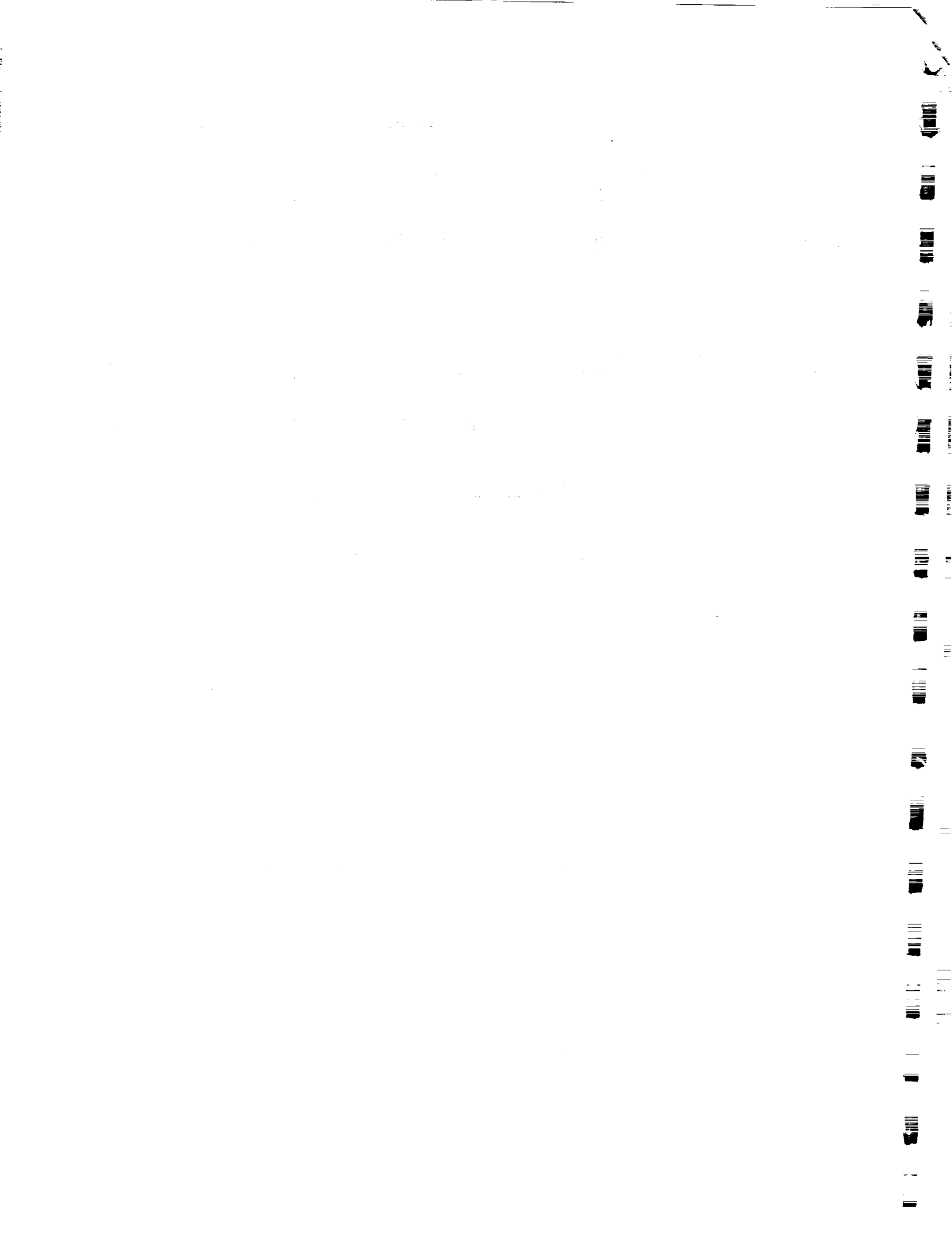


Figure 36	AEROEXEC output (vortex calculations: coefficients from potential calculation) .	141
Figure 37	AEROEXEC output (vortex calculations: lift coefficients and incremental lifts and drags)	142
Figure 38	AEROEXEC output (vortex calculations: performance summary)	143
Figure 39	AEROEXEC output (individual rotor perfor- mance summary, after vortex calculations)	144
Figure 40	AEROEXEC output (steady interference velocity field calculation)	145
Figure 41	AEROEXEC output (PRTPRF: counter-rotation performance summary)	149
Figure 42	AEROEXEC output (ADJUST)	151
Figure 43	AEROEXEC output (CPMAP, rear rotor onto front rotor)	157
Figure 44	AEROEXEC output (CPMAP, front rotor onto rear rotor)	158
Figure 45	AEROEXEC output (steady WMU vector calculation)	159
Figure 46	AEROEXEC output (unsteady WMU vector calculation)	162
Figure 47	NOISEEXEC output (observer position summary)	165
Figure 48	NOISEEXEC output (front and rear rotor operating conditions)	166
Figure 49	NOISEEXEC output (summary of noise results, by directivity)	167
Figure 50	NOISEEXEC output (summary of noise results at each frequency)	168
Figure 51	Listing of sample program to generate QWMU vector for sinusoidal gust	169
Figure 52	Listing of CRPBLK with changed default value for CRP tolerance CRPTOL	170



Summary

This is the user's manual for UCAP (Unified Counter-rotation Aeroacoustics Program), the counter-rotation derivative of the UAAP (Unified Aero-Acoustic Program). The purpose of this program is to predict steady and unsteady airloading on the blades and the noise produced by a counter-rotation Prop-Fan. The aerodynamic method is based on linear potential theory with corrections for non-linearity associated with axial flux induction, vortex lift on the blades, and rotor-to-rotor interference. The theory for acoustics and the theory for individual blade loading and wakes are derived in *Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise*, Volume 1 (NASA CR-4329). This user's manual also includes a brief explanation of the theory used for the modelling of counter-rotation.

Major sections of this volume include a general code overview, descriptions of input and output, installation instructions, and a listing of error codes.

I Introduction

This document describes the use and general structure of the Unified Counter-rotation propeller Aeroacoustic Program (UCAP), developed under NASA Contract NAS3-24222, Task Order 10. UCAP is the single and counter-rotation successor to the single rotation UAAP,* which is a computer program to predict the aerodynamic and acoustic performance of Prop-Fans using helicoidal lifting surface theory and a frequency-domain acoustic theory developed at Hamilton Standard in the 1980's (reference 1).

The major improvements of this version of UCAP over UAAP are:

The inclusion of counter-rotation. The steady interaction is modelled by perturbing the solution for one rotor by the mean velocity field caused by the other. These interaction velocities are assumed to follow streamlines.

Calculation of induced drag from blade Δc_p data instead of in the Trefftz plane. This was changed to include loading from the leading edge vortex and the tip edge vortex.

Inclusion of the vortex loading effects into the calculations of the induced velocity and the wake. The time average, non-linear axial momentum is satisfied by iteration.

Streamline contraction is added. This is modelled by forcing continuity along annuli defined by flow-field data.

Steady aerodynamic boundary conditions on the blades are calculated on conical surfaces defined by the local streamline angle.

The calculation of the required turning angle (for the flow tangency boundary correlation on the blades) has been revised. Instead of treating the axisymmetric disturbances (for example, those from the other rotor or from an external flow field) as perturbation angles, these are incorporated into the mean velocity triangle (see Figure 1).

The axisymmetric interaction component of the rotor-to-rotor interaction velocity is calculated from $\partial C_t / \partial x$, the local thrust loading, and $\partial C_p / \partial x$, the local power loading. This method requires less CPU time than the near wake formulations and will not significantly change interaction velocities at normal rotor spacings.

* Unified Aero-Acoustic Program.

Iterative correction for interaction velocity on both rotors
of a counter-rotation Prop-Fan is included.

II Theory

UCAP is a derivative of the earlier UAAP work; the details of the theory behind UAAP can be found in reference 1. The two major improvements over the interim version of UCAP, produced under Tasks I and II of this contract, are the incorporation of vortex loading into the induced flow calculation and the wake calculations, for both single and counter-rotation operation, and the modeling of contraction in rotor-rotor interference, which will be described below. UCAP works on the basis of perturbing each rotor with the velocity field produced by the other rotor. The steady loading upon a blade is divided into several parts: the potential part (subscript POT) is directly from lifting surface theory; it is calculated from

$$\{L_{POT}\} = [K]^{-1} \times \{W\}$$

where $\{L_{POT}\}$ is a vector representing the potential loading, $[K]^{-1}$ is the influence coefficient matrix, and $\{W\}$ is the turning angles required to maintain flow tangency along the blade surface. The secondary loading (that portion of loading due to induced flow) is calculated based on momentum theory using the thrust and torque at each control point and the mass flux through the rotor. The methods for calculating the secondary loading and vortex loading (the portion of the loading from the leading edge, side edge, and tip edge vortices) are described in reference 1, but the application is different. In UAAP, the calculation of the induced flow and the wake depended only upon the potential loading, $\{L_{POT}\}$. The steady potential loading was the result of non-linear iterations, where the C_p and C_t resulting from each step were used to compute a new induced flow. This was repeated until the change in C_p was small. The final potential load was then used to drive the Near Wake Calculation. The vortex loading was attached to the final performance values but never included in either the loading to drive the Near Wake Calculation or in the induced flow calculation. In the present program, the induced flow is calculated before and after the calculation of the vortex loads, so the influence of non-linear lift is included in the inflow field. The Near Wake routine calculations are driven by $\{L\}$, which includes the vortex load and is obtained by:

$$\{L\} = \{L_{POT}\} \cdot ((\partial C^* / \partial x) / (\partial C_t / \partial x))$$

where $\partial C^* / \partial x$ includes the effect of vortex loading and $\partial C_t / \partial x$ includes potential loads only.

The flow chart in Figure 2 shows a schematic of the method used in counter-rotation operation for the steady aerodynamic solution. Single rotation operation bypasses steps M through V, but is otherwise similar.

Streamline contraction is a result of the conservation of mass. In UCAP this is done by dividing the flow into streamtubes which are defined by the flow field entered by means of the VELGRADS command (see Section IV, "Input Description"). If no external flow field is defined, initial streamlines will be based on the hub and tip radii of the front and rear rotors. The locations where these streamlines intersect the rotors are calculated after every steady iteration. The new locations of the streamlines at the rear rotor are computed by calculating the flow rate in each streamtube and adjusting the annular areas in order to enforce incompressible continuity. For the streamline locations on the rear rotor, the flow rate in each streamtube where it crosses the forward rotor is calculated from the induced velocity, the interference velocity caused by the rear rotor, the velocity due to the external flow field, and the streamtube area. Since the velocity where that stream-tube crosses the rear rotor is known, continuity will determine the stream tube area at that location. This is repeated until all streamlines on the rear rotor are relocated. The new locations of the streamlines where they intersect the front rotor are calculated in a similar manner: the streamtube areas on the rear rotor are held fixed while the streamlines on the front rotor are adjusted to satisfy continuity.

The streamtubes defined by the last steady iteration are used for the calculation of the unsteady rotor-to-rotor interferences. A separate document (reference 4) contains a more detailed explanation of the theory used in UCAP.

III Program Organization

UCAP is a large program, with about 30000 lines of source code excluding comments. It is divided into several modules, which communicate via common blocks, argument lists, or files. These are:

Control Module — Controls the program flow, monitors convergence of the steady aerodynamic iterations, and performs some housekeeping functions, such as assuring that the common blocks are properly loaded with default data.

Input Module — Reads the data entered by the user. Entered data are placed into named common blocks for access by the rest of the program. The input module will also set the default values for the appropriate input parameters which have them.

Blade Geometry Module — Converts the geometry data entered in any of the three available coordinate systems to the coordinate system used internally.

Steady Aerodynamics Module — Performs the calculations required for the solution of the steady aerodynamics, and passes the ΔC_p 's calculated to the Steady Loads Module, which performs the integrations needed to get C_p , C_l , and applies the vortex loading to get C_t^* and C_p^* . The influence coefficient matrices and thickness vectors are calculated here. The forward rotor influence coefficient matrix is written to file FWD000. The rear rotor is written to file AFT000. For single rotation, the file will be SRP000.

Steady Loads Module — Integrates ΔC_p 's to get C_p , C_l , $\partial C_p / \partial x$, and $\partial C_l / \partial x$, and applies the vortex loading corrections, as in UAAP, to get C_t^* , C_p^* , $\partial C_t^* / \partial x$, and $\partial C_p^* / \partial x$. This module also writes the steady portion of the input data file for the Noise Module.

Unsteady Aerodynamic Module — Calculates the complex ΔC_p 's resulting from a given disturbance field and writes the unsteady portion of the input data file for the Noise Module. The unsteady influence coefficient matrices calculated in this module are written to external files with names of the form AFT001, AFT002, FWD001, FWD002, etc., where the number is the interaction harmonic order. For single rotation all matrices will be written to a file named SRP000.

Steady Interaction Wake Module — Uses $\partial C_t^* / \partial x$ and $\partial C_p^* / \partial x$ to calculate the velocity field caused by one rotor upon the other. This approach discards influence of the chordwise

loading distribution on the velocity field, which is considered negligible at reasonable rotor-to-rotor spacings.

Near Wake Module — Uses complex loading information supplied by the Steady Aerodynamics Module, with a correction for the vortex loads, to calculate the unsteady perturbation terms caused by one rotor upon the other. While the perturbations are unsteady, the wake is steady when viewed by an observer moving with the rotor generating the wake. When an inflow field incorporating unsteady components is input, the UCAP wake is based on the steady component only. The unsteady portion does not impact the wake. For single rotor operation, only, this module will calculate the velocities caused by the rotor at specified upstream or downstream points (WAKEEXEC command).

Noise Module — Calculates the radiated noise from data contained in an input data file at locations requested by the user.

Utility Routines — Includes sub-programs for interpolation, splining, data management, and printout. These routines are called from many places in the program.

Figure 3A shows the subroutine calling tree of the program. Figure 3B shows the subroutine cross reference listing. Figure 3C is a subroutine reference and purpose listing. Figure 3D shows the labeled common area reference listing.

UCAP uses a large number of named common blocks, but no unnamed (blank) common blocks, for data storage and for data exchange between modules. These are listed in Table I. Further information concerning the actual system requirements is in Section VII, "Program Installation".

IV Input Description

The primary input mode is expected to be a predefined input data set. Upon program execution the primary input file, file number 5, is immediately read and echoed to both the primary output file, file number 6, (to obtain a complete copy of the input on the output file) and to a scratch file, file number 11. All subsequent primary input is obtained by reading file number 11.

No other input files are required by the code except as the user may define for restart capabilities. Several scratch files are generated by the program; they are defined in the Section VIII, "File Requirements".

There are many input values which act as tolerances on iterations, or convergence criteria. These have been defaulted within the code to "recommended" values. Although they explicitly appear in the input description, they need not be input. Input data which need not be input appears at the end of each section, and the input location number appears within parentheses.

The next sections present a description of all the input necessary to run the code.

Commands

The code is command driven. Commands are used to identify the input sections, the input values, and to execute various functions of the code. Sub-commands are used to execute options within functions. The general input format of the command is:

(starting in column 1)
COMMANDX(SUBCOMMD) where "COMMANDX" is an 8 character word, including trailing blanks, and "SUBCOMMD" is also an 8 character word, including trailing blanks.

Load

Some commands require that numerical input must be read in next. For this purpose a location-specified, free-field input routine is used which reads between columns 1 and 72. Locations for input are indicated by "L" followed by a number indicating the desired start of a location.

Some of the location specified input controls integration mesh sizes, Fourier series convergence, and other program tolerances. These locations have been identified by parenthesis () around the location number and can usually be ignored by the user. However, if these values are input, the parenthesis () should be omitted from the location field.

Input for this "LOAD" format is illustrated below:

(starting in column 1)
C THIS IS AN OPTIONAL COMMENT RECORD (or Records)
L 10 1.1 2 3.5
C THIS IS ANOTHER OPTIONAL COMMENT RECORD (or Records)
12.7 13.1
L 91 6.5
END

This will cause the locations shown below to have the following values:

LOCATION	VALUE
10	1.1
11	2.0
12	3.5
13	12.7
14	13.1
91	6.5

Notes: "Scientific notation" is not allowed, e.g. 2.1 E+03 is not allowed. Implied repetitions are not allowed, e.g. 3*2.1 is not allowed. The "END" record is required to terminate each entry into the LOAD routine.

Command Summary

A list of accepted commands is shown below. Since this is a command driven code, command order is important, and therefore the commands are listed below in the required logical sequence for execution.

HEADER	-	Input page header cards
RUNPARMS	-	Input flight parameters
CRPPARMS	-	Input counter-rotation parameters
AIRPARMS	-	Input options for 2-D drag look-up.
BLADEGEO	-	Input propeller/blade geometry (2-D, RXY or XYZ coordinates).
LSTPARMS	-	Input options to panel aero code.
NOIZPARM	-	Input options to the noise portion of the code.
VELGRADS	-	Input axial velocity field on a defined grid.
VORTPARM	-	Input options to vortex flow calculation.
WAKEPARM	-	Input options to wake calculation.
INTERPRM	-	Input options for rotor-to-rotor interaction calculations
AEROEXEC	-	Execute the aero code.
WAKEEXEC	-	Execute the wake calculation.
NOIZEXEC	-	Execute the noise portion of the code.
ENDCASE	-	End of input and calculations for the current case.
ENDJOB	-	End of job, terminate the program.

Specific Input Description

Input requirements/options are provided below for each command, in the order listed above.

HEADER:

This command enters page heading records. Records following the HEADER command are sequentially read until an "END" command is found. Up to 10 page heading records may be entered.

RUNPARMS:

This command enters run parameters using "LOAD" format. The location, default, and input descriptions are:

LOC.	Default	Variable	Description
1	0	RUNBUG	Debug Option, 1 turns on.
2	59.0	QDEGF	Ambient temperature, °F.
3	1.0	QRHOR	Ambient density/Sea Level Std. density.
4	0	QADV F	Advance ratio, $J = V_o/nD$, for a single rotor or for the forward rotor of a counter-rotation Prop-Fan.
5	0	QMX	Free-stream Mach number.
16	0	QADV R	Advance ratio, $J = V_o/nD$, for the aft rotor of a counter-rotation Prop-Fan.

CRPPARMS:

This command is used to control counter-rotation operation of the program and to enter certain parameters specific to counter-rotation, such as the rotor-to-rotor spacing. If this command is omitted, UCAP will run in single rotation mode; this is to permit existing UAAP input data to be used for single rotation without change.

LOC	Default	Variable	Descriptions
1	0.0	CRPBUG	Printout control. 0: Minimal printout 1: Printout specific data after each front/rear rotor iteration
2	0.0	SWITCH	0.0: Run single rotation. This was chosen to ensure compatibility with UAAP data decks. 1.0: Run counter-rotation
3	-1.0	SPACE	Distance between rotor pitch change axes, normalized by forward rotor diameter. For counter-rotation cases, this <i>must</i> be entered by the user; if nothing is entered the program will stop.
4	0.0	COUNT	Number of front-rear rotor iterations. Maximum is 25.
6	1000.0	CRPTOL	Tolerance. When the change in power coefficient between iterations is less than this value, the steady performance is considered converged. Values less than 1.0×10^{-5} will be reset to 10000. This value was selected for convenience in program debugging. The user must enter a value less than 1. for iteration to occur. See Appendix for recommended values.

7	0.0	FWDHRM	Highest forward rotor wake harmonic to use for the excitation of the rear rotor.
8	0.0	AFTHRM	Highest rear rotor induction field harmonic to use for the excitation of the forward rotor.

LSTPARMS:

This command enters input options to the panel aero portion of the code using "LOAD" format. This command has two sub-commands: AFT and FWD. Use LSTPARMS(FWD) to enter parameters for the forward rotor in counter-rotation cases. Use LSTPARMS(AFT) to enter parameters for the rear rotor in a counter-rotation case. Use LSTPARMS, with no sub-commands, for single rotation cases. The location, default value and input description are:

(* See Figure 4 for pictorial description)

LOC.	Default	Variable	Description
1	0	ZSTBUG	Debug Option, 1 turns on.
* 2	10	QNCP	Number of chordwise panels, maximum of 10.
* 4	8	QNSM	Number of spanwise modes (control point radii). Maximum of 10.
20	1	QPART1	0 generate $[K]^{-1}$ and W_T . 1 generate $[K]^{-1}$ and read W_T . 2 read $[K]^{-1}$ and generate W_T . 3 read in $[K]^{-1}$ and W_T . The code requires an inverse kernel matrix $[K]^{-1}$ and thickness vector, W_T , to obtain the aerodynamic loading on the blade. The $[K]^{-1}$ matrix and W_T vector require a significant amount of CPU time, and an option to utilize

previously generated $[K]^{-1}$ matrices and W_T vectors has been incorporated into the code.

Note: For counter-rotation operation, the program requires that the $[K]^{-1}$ matrix be available for every QQ and QK (see below). If any $[K]^{-1}$ matrix is required for a given rotor, all $[K]^{-1}$ matrices must be calculated for that rotor.

21 0 QQ

Order of unsteady loading, harmonic, = 0 for steady loading.

For single rotation operation, this parameter must be set to a value greater than zero for unsteady aerodynamics. For counter-rotation, enter 0, as this parameter is calculated for the unsteady rotor-to-rotor interactions.

22 0 QK

Number of circumferential modes for unsteady loading, = 0 for steady loading.

For single rotation operation, this parameter must be set to a value greater than zero for unsteady aerodynamics. For counter-rotation, enter 0, as this parameter is calculated for the unsteady rotor-to-rotor interactions.

28	2	QNBOPT	= 1 for supersonic leading edge element, use when supersonic flow expected at leading edge. = 2 for subsonic leading edge element.
29	10	QITNON	Max number of non-linear iterations, for single rotation operation. =0 for linear calculation. This parameter is ignored for counter-rotation operation.
* 101	.2, .35, .45, .55, .65, .75, .85, .95	QZAR	Spanwise locations of control point radii, The number of these must agree with QNSM, fraction of R_{up} .
* 141	.5, .5, .5, .5, .5, .5	QCONTP	Chordwise location of control points within each panel normalized to the panel width. There must be QNSM of these. All control points are at the same location at a given radius.
181	.4, .4, .4, .4, .4, .4	QCHW	Width for chordwise averaging of downwash, normalized to panel width. There must be QNSM of these input. The downwash averaging width is constant at a given radius.

51	0, 0	QWMU	<p>Complex downwash vector for flowfield for external to propeller unsteady loading calculation. These can be obtained from Section 13, equation (13.8) of reference 1. A routine to generate these is in the appendix. The values of QWMU must be input sequentially starting in location 351, as real part, imaginary part for each control point across the 1st spanwise station, and then proceeding outward along the blade span. Thus, there must be (QNCP*QNSM) pairs of values input for QWMU.</p>
----	------	------	--

The following input locations may be ignored.

(3)	.02	QDR	Radial extent of singular integral at control point radius for wake calculation radius.
(5)	1024	QN	Number of points in FFT for terms in kernel integration, max. of 2048, must be a power of 2.
(6)	.004	QDELTA	Axial step size for FFT.
(7)	4	QMODOP	Spanwise mode shape option (use default value).
(8)	.0001	QTOLF	Tolerance for W (omega) integration.
(9)	.001	QTOLT	Tolerance for other integrations.
(10)	.005	QTOLS	Tolerance for summations
(11)	20	QMM1	Loop limit for harmonic summation in wake kernel.

(12)	30	QMM2	Loop limit for harmonic summation in bound kernel.
(13)	10	QMM3	Loop limit for harmonic summation in thickness vector.
(14)	--	QITABK	File number allocated for $[K]^{-1}$ matrix storage. The default is 8 for single rotation or for the FWD sub-command and 18 for the AFT sub-command.
(15)	--	QITABT	File number allocated for W_T (thickness vector) storage. The default is 9 for single rotation or for the FWD sub-command and 19 for the AFT sub-command.
(16)		QINT4	Not currently used.
(17)	0	QPRINT	Additional debug print - not recommended.
(18)	0	QPRIN1	Additional debug print - not recommended.
(19)	0	QPRIN2	Additional debug print - not recommended.
(23)	.025	QKDOWN	Radial step size for non-singular bound kernel
(24)	.010	QKSTART	Width of singular region for bound kernel integration
(25)	5	QMM4	Loop limit for summation in sound power calculation.
(26)	.9	QMBLEN	Trailing edge effective Mach number for blending to supersonic trailing edge elements.

(27) 1024 QNO

Number of points in FFT
integration for $n = 0$
term in kernel,
max = 2048, must be a
power of 2.

(221) .002 QINMES

Step size for radial in-
tegration in wake kernel.

BLADEGEO:

This command enters the propeller/blade geometry using the "LOAD" format. For any propeller and flight condition, the shaft power required, and the thrust produced by the propeller are a function of the blade angle. In using this code it is recommended that the blade angle be adjusted so that the power or thrust calculated by this program matches a desired value. (see Sections 3 and 6 of reference 2 for further explanation).

Nine sub-commands exist to allow input of the geometry in different forms:

For single rotation these are:

BLADEGEO(2-DCOORD), BLADEGEO(RXYCOORD), and BLADEGEO(XYZCOORD).

For the forward rotor in counter-rotation these are:

BLADEGEO(2-DCOFWD), BLADEGEO(RXYCOFWD), and BLADEGEO(XYZCOFWD).

For the aft rotor in counter-rotation these are:

BLADEGEO(2-DCOFT), BLADEGEO(RXYCOFT), and BLADEGEO(XYZCOFT)

The 2-DCOORD, RXYCOORD, and XYZCOORD sub-commands must not be used in counter-rotation operation. The 2-DCOFWD, RXYCOFWD, XYZCOFWD, 2-DCOFT, RXYCOFT, and XYZCOFT sub-commands must not be used in single rotation. These are described below.

BLADEGEO(2-DCOORD)

BLADEGEO(2-DCOFWD)

BLADEGEO(2-DCOFT):

These sub-commands all use the same form of the blade geometry, which is expected to be the most widely used. The 2-DCOORD sub-command is used for single rotation cases, 2-DCOFWD is used for the forward rotor of a counter-rotation Prop-Fan, and 2-DCOFT is used for the aft rotor of a counter-rotation Prop-Fan. Input takes the form of the spanwise variation of thickness ratio, chord/diameter ratio, twist, airfoil section designation and stacking axis coordinates. This command(sub-command) will calculate the blade surface coordinates and interpolate these into a form required by the other parts of the program. To insure that there are no errors in the blade output description, only a limited amount of extrapolation of the input blade coordinates is allowed. Thus, it is best to provide input stations, X, and streamline angles, SLA, which will define the root and tip sections of the blade such that the output stations, ZBLDST, can be interpolated and not extrapolated. The code requires exactly ten (10) inputs defining X. The input described below is illustrated in Figures 5 and 6.

Note that there are empty locations in the input. These are not used by the program.

LOC.	Default	Variable	Description
1	0	BLDEBUG	Debug option, 0 is off, 1 is on.
31	0	BLADE	Number of blades
32	0	D	Propeller diameter, ft.
33	0	SCO	Propeller hub/tip ratio
41-50	0	X	Spanwise input stations, 10 are required, fractions of R_{up} .
51-60	0	HOB	Spanwise airfoil maximum thickness/chord ratio.
61-70	0	BOD	Spanwise chord/diameter variation.
71-80	0	CLD	Spanwise variation of design lift coefficients.
81-90	0	DTHET	Spanwise twist variation, in degrees. Twist should be input such that twist at the 75% radius is 0.
347	0	THTDES	The 75% radius value of blade angle at which the blade is to be "de-signed", degrees.
348	0	THTCUT	The 75% radius value of blade angle at which this calculation is to be run, degrees.

Note: Propeller blades are assumed to be "designed" at one value of blade angle. The input values of thickness/chord, chord/diameter, camber, twist and stacking line are assumed to be defined at the value of blade angle in Location 347. Location 348 defines the blade angle at which this calculation is to be run.

381-390	0	SLA	Spanwise variation of streamline angle, degrees. Blade airfoil sections are assumed to be on cones which approximate the streamlines through the propeller. This input is the cone half-angle, positive as shown in Figure 5.
711-720	0	XSWP	Spanwise variation of X coordinate of mid-chord stacking line, fraction of R_{tip} , see Figure 6.
721-730	0	YSWP	Spanwise variation of Y coordinate of mid-chord stacking line, fraction of R_{tip} , see Figure 6.
731-740	0	ZSWP	Spanwise variation of Z coordinate of mid-chord stacking line, fraction of R_{tip} , see Figure 6.
900	21	ZNPCOV	Number of output stations in the chordwise direction, max 49.

901-949 0., 5., PCTCHD
 10, 15, 20
 25, 30, 35,
 40, 45, 50,
 55, 60, 65,
 70, 75, 80,
 85, 90, 95,
 100

Chordwise location of
 output stations. Both
 upper and lower airfoil
 surfaces are output at
 the same chordwise
 locations, % chord.

950 21 ZNIS

Number of output stations
 in the spanwise dir-
 ection, max of 49.

951-999 .10, .30, ZBLDST
 .40, .50,
 .55, .60,
 .65, .70,
 .75, .80,
 .825, .85,
 .875, .90,
 .925, .95,
 .96, .97,
 .98, .99
 1.0

Spanwise location
 stations at which
 the blade surface will be
 defined, radius ratios,
 r/R_{tip} .

The following input locations may be ignored.

(346) 2 SWPOPT

Input sweep option. The
 default value is re-
 quired.

(349) 1 ZKCUT

Type of airfoil section
 defined
 0 planar,
 1 conical. (default).
 2 cylindrical

(741-751) 1 BAFL

Integer characterizing
 the 2-D airfoil at each
 spanwise station. Only
 NACA 16 series airfoils
 can be generated with
 this deck.

BLADEGEO(RXYCOORD)
BLADEGEO(RXYCOFWD)
BLADEGEO(RXYCOAFT):

An optional method for input of the blade geometry has been provided. This form allows for up to 50 input stations. Additionally, it requires a table of the displacement of the mean camber line from the chord line. The RXYCOORD sub-command is used to enter data for single rotation cases. The RXYCOFWD and RXYCOAFT sub-commands are used to enter data for the forward and aft rotor, respectively, of a counter-rotation Prop-Fan. This option requires that the blade sections being described be on cylinders whose axis is the centerline of rotation. The input is illustrated in Figures 7 through 9.

LOC.	Default	Variable	Description
1	0	BLSBUG	Debug Option, 0 is off, 1 is on.
2	0	STANO	Number of spanwise input stations, max of 50.
3	0	PCTNO	Number of chordwise input stations, max of 50.
4	0	DIAMET	Propeller diameter, ft.
5	0	SPINNER	Propeller hub/tip ratio.
6	0	BLADES	Number of propeller blades.
51-100	0	CTSTA	Spanwise input stations, r/R_{tip} .
101-150	0	PCTCD	Chordwise input stations, %chord.
At each spanwise station			
151-200	0	THKOB	Maximum blade thickness, fraction of chord.
201-250	0	CHDOD	Blade chord, fraction of diameter.

251-300 0	CAMBR	Equivalent NACA Series 16 camber. Obtained by taking the <u>non-dimensional</u> maximum height of the blade mean camber line / .05515 , fraction of chord.
301-350 0	TWIST	Blade section chord angle, deg.
351-400 0	XMC	X-coordinate of mid-chord stacking line, fraction of R_{up} .
401-450 0	YMC	Y-coordinate of mid-chord stacking line, fraction of R_{up} .
451-500 0	ZMC	Z-coordinate of mid-chord stacking line, fraction of R_{up} .
501-550 0	XSLA	Streamline angle, deg. This is the flow angle relative to the center-line of rotation, and is used in the sweep angle calculation.

Blade mean camber line displacement table.

1003	0	PCTND	Number of chordwise points in mean camber line displacement table.
1004	0	STAND	Number of spanwise points in mean camber line displacement table.
1005	0	CAMLN	Ascending array of chord fractions, PCTND values.

Followed immediately by :

1005 0 CAMLN
+
PCTND

Ascending array of spanwise radii, fraction of R_{tip} . Starting after last input location, STAND values.

Followed immediately by :

1005 0 CAMLN(I,K)
+ I=1,STAND
PCTND+STAND K=1,PCTND

Array (PCTND*STAND) of mean camber line displacements from chord line at each radial station, at 1st chordwise location, fraction of chord. This is followed by a similar array for the 2nd chordwise location, and continues through the PCTND chordwise location.

BLADEGEO(XYZCOORD)
BLADEGEO(XYZCOFWD)
BLADEGEO(XYZCOAFT):

This form of blade geometry inputs the blade description in XYZ coordinates of each blade surface. The XYZCOORD sub-command is to be used for single rotation. For counter-rotation operation use the XYZCOFWD sub-command to enter data for the forward rotor; use the XYZCOAFT sub-command to enter data for the aft rotor. Figure 10 illustrates the coordinate system used. Note that this XYZ coordinate system is different than the 2-D or the RXY system.

LOC.	Default	Variable	Description
1	0	BLDEBUG	Print option. 0 is minimal 1 is additional.
2	0	DIAME	Propeller Diameter, ft.
3	0	SPINN	Hub to tip ratio.
4	0	BLADE	Number of blades
5	0	STINN	Number of radial stations in input.

6	0	CDINN	Number of chordwise stations in input.
7	0	STOUTN	Number of output radial stations needed to define the blade.
8	0	CDOUTN	Number of output chordwise stations needed to define the blade.
51	0	STOUTV	Values of radial stations, fraction of radius.
101	0	CDOUTV	Values of chordwise stations fraction of chord.

An "END" record is required to terminate the "LOAD" input. The "END" record is immediately followed by the xyz coordinates of the blade as follows:

For each of the STINN radial input stations the following input records are required:

- a) A label record
- b) For each of the CDINN chordwise input stations the X, Y, and Z coordinates of the face (pressure) side of the blade are input. With one set of X, Y, Z, coordinates in free-field format per record. The units are inches.
- c) Another label record
- d) For each of the CDINN chordwise input stations the X, Y, and Z coordinates of the camber (suction) side of the blade surface are input. With one set of X, Y, Z coordinates in free-field format per record. The units are inches.

VELGRADS:

This command will input or initialize the axial velocity ratio at the propeller. These ratio may be due to the spinner-hub and or nacelle effects on the freestream flow, but the result must appear to the code as an axisymmetric flowfield.

LOC.	Default	Variable	Description
1	0	V1BUG	Debug option
2	0	V1OPT	Velocity ratio input option, 0 : initialize velocity field to 1.0, fraction of freestream velocity. No further input is required. 1 : input the velocity ratio.

For option V1OPT=1. only:

The axisymmetric velocity ratio is input on a grid of radial and axial points which encompass the blade outer boundaries. The flowfield values are interpolated at specific "nodal" points required by the code.

3	0	VINRD	Number of radial stations in grid.
4	0	VINAS	Number of axial stations in grid.
5	0	VIVRF	Reference velocity, by which local velocities are normalized, same units as VIRD, VIVV, and VIAX.
6	0	VITIP	Reference radius, by which local radii are normalized, same units as VIRD and VIAX.

7	0	VICLL	Centerline location. The axial location of the forward (or only) blade pitch axis is assumed to be 0. This value is subtracted from the input values of VIAX after input so that the axial location of the forward (or only) blade centerline will be at 0. Same units as VIAX.
---	---	-------	---

The following inputs are repeated for each of the axial stations in the grid, (K=1,VINAS).

25	0	VIRD(I,K) I=1,VINRD	Radial locations of 1st set of up-stream grid up-stream grid points, same units as VITIP.
25+		VIVV(I,K) I=1,VINRD	Velocities at VIAX(I), VIRD(I), I=1,VINRD same units as VIVRF.
25+		VIAX(I,K) I=1,VINRD	Axial locations of VIVV(I), same units as VITIP.

WAKEPARM:

This command provides input parameters to the propeller wake calculation procedure. This input is used in both the performance calculations, and in the "Wake" calculation option. The variables used for propeller efficiency and wake calculation are listed below.

LOC.	Default	Variable	Description
1	0	WAKBUG	Debug option. 1 print WAKEPARM input data. 0 do not print data.
6	1	YIPLT	Wake output. 1 is on 0 is off.
8	1	YNPSKN	Skin friction drag. 1 : included, 0 : not included.

20	0	YIPRT	Output option: 0 : no output 1 : V_r/V and V_x/V 2 : Fluctuating lift
23	0	YIVWK	The viscous wake shape is described by 1 of 3 options: 0 : gauss pulse 1 : cosine squared 2 : cosine
25	11	YNORPE	No. of output radii.
751	.24, .35, .45, .55, .65, .75, .80, .85, .90, .95, .98	YROUTP	Output radii, r/R_{up} .

The following input locations may be ignored.

(2)	.05	YK	Spanwise integration mesh size, fraction of radius.
(9)	.0001	YTOL	Fourier series sum convergence tolerance.
(10)	99	YMM1	Max. no. of Fourier coefficients to calculate, max. of 99.
(12)	.001	YTOL1	Tolerance for high frequency form of Fourier coefficient.
(13)	0	YLASTM	Last Fourier coefficient for detailed output.
(16)	0.7	YZO	Origin of special routine for interpolation of circulation curve.
(17)	0.5	YZNORM	Circulation curve normalizing factor.
(18)	1.0	YAOPT	0 to not iterate on induced angle.

(21) 0

YMM2

Turns on diagnostic print
for Fourier coefficient
up to YMM2 when YIPRT =
2.

The following inputs are required in addition to the above if wakes are to be calculated. Output radii are divided into those within the tip radius, YNOR, and those beyond the tip radius, YNPX.

LOC.	Default	Variable	Description
4	0	YNOR	Number of output radii which are less than or equal to 1.0 (within tip radius).
5	0	YNPX	Number of output radii which are greater than 1.0 (outside of tip).
50	0	YXNCS	No. of output axial locations, max of 10 at each radius.
51	0	YXMMU	No. of Fourier coefficients used in calculation of chordwise wake component.
52	0	YXMMV	No. of Fourier coefficients used in calculation of radial wake component.
53	0	YXMMW	No. of Fourier coefficients used in calculation of downwash wake component.
351		ROUT	Output radii, fraction of radius. There should be YNOR+YNPX of these.
701	0	YARRY(I,K) I=1,YXNCS	Output axial locations, fraction of radius, for 1st output radius. There should be YXNCS of these.

11	0	YARRY(I,K) I=1,YXNCS	Output axial locations, fraction of radius, for second output radius. There should be YXNCS of these.
721	0	YARRY(I,K) I=1,YXNCS	Output axial locations, fraction of R_{up} , for third output radius. There should be YXNCS of these.

For K=1,YNOR+YNPX

The following input location may be ignored.

(54)	0.01	YFPHW	Width of averaging func- tion for wake calcula- tions = X/R_{up} .
------	------	-------	--

AIRPARMS:

This command will input options which are used to obtain the 2-D airfoil drag from built-in tables of lift and drag coefficients.

LOC.	Default	Variable	Description
1	0	AIRBUG	Debug Option, 1 to print

The following input locations may be ignored.

(2)	24	AIRNUM	2-D Airfoil data pack number wanted for this run. Currently, only NACA 16 is available in this code.
(3)	5	AIRTPY	0 : Isolated 2D airfoil 1 : Isolated 2D airfoil w/cascade correction. 4 : Isolated 2D airfoil w/sweep correction. 5 : Isolated 2D airfoil w/sweep and cascade.
(13)	0	AIRCOR	0 : no drag correction input 1 : drag correction input

(15)	0	CDMLT	2D drag multiplier, used if AIRCOR = 1.
(17)	0	DCDT	2D drag increment, used if AIRCOR = 1.

CDMLT and DCDT are used to alter the drag of the stored airfoil data. They may be used to simulate another airfoil, to account for a rough airfoil or provide a better match with test efficiency. The altered drag coefficient is computed as:

$$C_{D(\text{altered})} = C_D * CDMLT + DCDT$$

NOIZPARM:

This command will input the options which are used to control the acoustic calculations.

NOTES: B is number of blades, M is noise harmonic order
B * ZMMAX must be less than 1001
MX is flight Mach number (may not be 0 for near-field calculation)

LOC.	Default	Variable	Description
1	0	ZNZDBG	Debug option : 0 no print; 1 print input parameters; 2 print file 50 input.
2	0	ZNFIND	0 for far-field theory 1 for near-field theory
3	1	ZMMAX	Max noise harmonic order group to calculate.
4		ALT	Distance from prop axis to observer, ft.
9		ZNX	Number of axial directivities for noise calculations, 20 max.
10	1	ZXORX1	Axial directivities are 1 : visual or 0 : retarded.
11		X1	Visual observer positions along axis (+ ahead of prop),ft. (calculated if X is input).
or			
31		X	Retarded positions observer, ft. (calculated if X1 is input).

59	1	ZIBLW	1 to add boundary layer and wake displacement thickness to blade thickness monopole noise. 0 to omit (for comparison with other predictions).
69	90.	PHIF	Azimuthal observer directivity angle for unsteady loading, degrees to front rotor — normally use the default. PHIF increases in the direction of rotation; zero corresponds to the phase reference position for calculation of unsteady air loads. Thus, the observer position is specified relative to the unsteady flow field reference.
70	90.	PHIR	Azimuthal observer directivity angle for unsteady loading, degrees to rear rotor. Important only when BPFF = BPFR. Gives the phase difference between rotors. PHIR increases in the direction of rotation; zero corresponds to the phase reference position for calculation of unsteady air loads. Thus, the observer position is specified relative to the unsteady flow field reference.

The following input locations may be ignored.

(51)	10	ZJMINI	With ZNJ1, controls chordwise integration mesh.
(52)	8	ZNJ1	Number of chordwise points = ZJMINI + M + B * ZNJ1, 1001 max pts.

(53)	10	ZJMIN2	Used with ZNJ2, controls spanwise integration mesh.
(54)	10	ZNJ2	Number of spanwise points is JMAX (must be less than 2001) which is calculated as follows : if ZNJ2 > 0, JMAX = ZJMIN2 + M*B*ZNJ2; if ZNJ2 < 0, JMAX = ZJMIN2 - ZNJ2 if ZNJ2 = 0, JMAX = ZJMIN2 + ZNJ2 points/phase cycle.
(55)	6	ZIW	Output file number.
(56)	1	ZSTART	Start harmonic order.
(57)	1	ZMINC	Increment in harmonic order.
(58)	2	ZLHSOR	Indicates what type of unsteady flow: 1 = blade wakes; 2 = flowfield.
(60)	0	ZPRUNS	If not 0, print diagnostic unsteady loading noise table.
(61)	0	ZITRAP	If not 0, max diagnostic print.
(62)	0	ZNFOUT	If not 0, print harmonic table to file number ZNFOUT; allocate appropriately.
(63)	0	ZKK	See note below.
(64)	0	ZKXTND	See note below.
(65)	10	ZKMIN	See note below.
(66)	10	ZOMEGA	See note below.
(67)	0	ZIPEXT	If not 0, print load diagnostics.

(68)	0	ZIPSIC	If not 0, do "instant" quadrupole noise calculation (not recommended).
(71)	1	ZNAIR	Code for airfoil thickness distribution (specify for all radial stations): 1 = series 16 3 = series 64 5 = series 65 7 = biconvex parabolic (analytic) 8 = 4 digit series

ZKK, ZKXTND, ZKMIN, and ZOMEGA :

In the near-field option, the program evaluates a Fourier transform numerically using rectangular integration. The range for this frequency integration is $1/(1+MX)$ to $1/(1-MX)$, where MX is the flight Mach number. The number of steps in the integration range determines the trade-off between precision and running time. The integrand is typically a fluctuating quantity whose rate of oscillation, dI/dw , is computed by the program as a function of several factors such as harmonic order, Mach number, and observer position. To achieve uniform precision over a range of conditions, the program determines the number of points (ZKK) in the frequency integration range from two input numbers: the first is the minimum points in the range (ZKMIN) and the second is the number of mesh points per oscillation of the integrand (ZOMEGA). The number of integration points is then $ZKK = ZKMIN + ZOMEGA * dI/dw$. Default values are $ZKMIN = 10$ and $ZOMEGA = 10$, which from numerical tests give a reasonable compromise between precision and running time. If the user wishes to experiment, he can override either of the two default values.

Reducing the number of points will reduce running time and storage requirements, but also reduce the precision of the calculation. Determining the satisfactory level of tradeoff between precision and running time for other than the defaults is up to the user.

In some cases a significant contribution to the noise can be caused by frequencies outside the range of frequency integration noted above. To account for this, ZKXTND points are included outside both the upper and lower bounds of the integration. If ZKXTND equals zero then it is automatically computed by the program, otherwise the input value of ZKXTND is used. However, $ZKK + 2*ZKXTND$ must be less than 401. If this is not true then the code will reduce ZMMAX by one until this condition is met.

INTERPRM:

This command inputs parameters for the control of the non-zero harmonic terms in the calculation of the interference between the front and rear rotors in counter-rotation cases. These are a sub-set of the WAKEPARM parameters. Normally, these default values should be used.

LOC	Default	Variable	Description
-----	---------	----------	-------------

The following locations are optional and may be ignored:

(1)	0.0	INTBUG	Printout control: set to 1 to increase amount of printout regarding inter-rotor wake.
(2)	0.05	INTXK	Spanwise integration mesh size, fraction of R_{ip} .
(3)	0.7	INTZO	Origin of special routine for interpolation of circulation curve.
(4)	0.5	INTZNM	Circulation curve normalization factor.
(5)	1.0	INTAPT	0 to not iterate on induced angle.
(6)	1.0	INTVWK	The viscous wake shape is described by one of three options: 0: Gaussian pulse 1: cosine squared pulse 2: cosine pulse
(7)	0.01	INTFPH	Width of averaging function for wake calculation, in terms of R_{ip} .
(8)	1.0	INTSKN	Skin friction drag. 1: included 2: not included
(9)	0.001	INTTOL	Fourier series sum convergence tolerance.
(10)	0.0001	INTOL1	Tolerance for high frequency form of Fourier series.

(11)	99.0	INTMM1	Maximum number of Fourier coefficients to calculate, limit of 99.
(12)	0.0	INTMMU	Number of Fourier coefficients used in calculating the chordwise component of the wake.
(13)	0.0	INTMMV	Number of Fourier coefficients to be used in calculating the radial portion of the wake.
(14)	0.0	INTMMW	Number of Fourier coefficients to be used in calculating the downwash portion of the wake.
(15)	0.0	INTPLT	Wake output; 1 is on; 0 is off.
(16)	0.0	INTPRT	Output option. 0: no output 1: print V_r/V and V_x/V 2: print fluctuating lift.

VORTPARM:

This command inputs the options which are available to control the Vortex Flow Aerodynamic calculations. This command has two sub-commands: FWD and AFT. Use VORTPARM(FWD) to enter parameters for the front rotor in a counter-rotation case. Use VORTPARM(AFT) to enter parameters for the rear rotor in counter-rotation cases. Use VORTPARM, with no sub-commands, for single rotation cases.

LOC.	Default	Variable	Description
1	0	VTXDBG	Debug option: if = 0, input not printed, if = 1, input printed.
2	1	DOLEAD	If = 1, then calculate additional lift due to leading edge vortex.
3	1	DOSIDE	If = 1, then calculate additional lift or radial force due to tip edge flow.
4	1	DOAUGL	If = 1, then calculate additional lift due to leading edge vortex shed over aft portion of blade at the tip (augmented lift).
5	.97	ZAUGFF	Radius at which augmented lift acts, r/R_{tip} .
6	0	TIPLOR	Indicates whether tip edge flow results in ex- tra lift (0) or radial force (1).

TIPLOR is set by the user to determine the type of edge flow.

0 for separated tip flow, where the tip vortex gives extra flow at the tip.

1 for attached tip flow which produces a radial tip edge force.

*The AFT and FWD subcommands are eight characters long. The trailing blanks are not required.

The following input locations may be ignored:

(7)	0	PRTPRF	1: print results on every iteration. 0: do not print results on every iteration
(8-57)	0.2, at all radii.	VTXDLX	Chord-wise distance from leading edge at which vortex loads are assumed to act, in terms of fraction of local chord. There is one value of VTXDLX for each output station in the spanwise direction, specified as ZNIS (location 950) in the 2-D coordinate inputs under blade geometry (BLADEGEO section above).

AEROEXEC(PRNTCASE):

This command(sub-command) will process all of the input and execute the code to the point where the Compressible Panel Method prints the data it has received. The aerodynamic calculations will not be performed. This is useful in verifying the input before doing the actual aero calculations.

AEROEXEC(EXECCASE):

This command(sub-command) will process all of the input and execute the aerodynamic calculations.

NOIZEXEC(EXECCASE):

This command(sub-command) will execute the noise calculation section of the code. This should be placed after the AEROEXEC record.

WAKEEXEC(EXECCASE):

This command(sub-command) will execute the potential and viscous wake calculations. This should be placed after the AEROEXEC or NOIZEXEC record. This command should only be used with single rotation operation of the code.

ENDCASE:

This command signifies the end of all commands for the current case, and is required.

ENDJOB:

This command will terminate execution, and is required.

V Output Description

This section presents a description of the output from the UCAP program and includes output print from AEROEXEC (the panel code performance calculation). The output from NOISEXEC (the noise calculation) is described in Section VI.

The output of this program expands on the output of the UAAP program (reference 3). The outputs of the blade geometry routines, the vortex routines, and the lifting surface (steady) solution routines have changed due to the improvements in the code: these changes are applicable to single and counter-rotation operation. Also, the program output has been expanded due to the addition of counter-rotation; the outputs for stream-line contraction, rotor-to-rotor interference velocities, and rotor control point location are new.

The debug option, described under the various input section commands, controls the scope of output. These options normally have values of either 0.0 (the default), for minimal printout, or 1.0, yielding additional output. Most pages have a title followed by the header information (entered via the HEADER command). The header consists of a brief description of the page contents. This includes, after the first colon, the subroutine name which is doing the printing of this page, 2) the input command option currently in effect, 3) the time and date at the start of the run, and 4) the program/version identification.

Output Description when DEBUG = 1

This output description follows the order shown in Section IV, "Input Description".

OUTPUT:

The output starts with an echo of the input data set, which is discussed in the input description, and shown in Figure 11.

RUNPARMS:

The debug option of 1. will print the page shown in Figure 12, which shows the input parameters, defined in the input section, along with the location number and the input or defaulted value.

CRPPARMS:

The debug option of 1 will print the page shown in Figure 13, which shows the parameters, defined in the input section, to be used for counter-rotation. FWD->AFT HARM. and AFT->FWD HARM specify the number of unsteady interference harmonics for the front rotor upon the aft rotor and the aft rotor upon the front rotor, respectively.

AIRPARMS:

Figure 14 presents the additional output for debug = 1. Again, the parameters are defined in the input section. A few lines of airfoil description are given, defining the airfoil selected, used to determine profile drag.

BLADEGEO:

Setting DEBUG = 1. in the BLADEGEO section of input yields an additional page of input definition, given in Figure 15. The sample shown in Figure 15 is for the forward rotor of a counter-rotation Prop-Fan. The items output and the form of the output is the same for either rotor of a counter-rotation Prop-Fan or the rotor of a single rotation Prop-Fan, so samples for those cases will not be included. Definitions of the parameters follow:

PARAMETER	DESCRIPTION
DEBUG	Debug option for additional printout.
BLADN	Number of blades.
DIAMETER	Propeller diameter, feet.
SCO	Inner-most blade station at 50% chord.
SWEEP TYPE	Defined in input as SWPOPT.
DESIGN ANGLE	Defined in input as THTDES.
RUNNING ANGLE	Defined in input as THTCUT.
TYPE CUT	Defined in input as ZKCUT.
X	Station radius/blade tip radius (R_{tip}).
T/B	Blade thickness/blade chord.
B/D	Blade chord/propeller diameter.
CAMBER	Design lift coefficient.
DELTA THETA	Blade twist, from plane of rotation, degrees.
XSWP	Defined in input.
YSWP	Defined in input.
ZSWP	Defined in input.

AIRFOIL TYPE	Defined in input as BAFL.
NO. OF % CHORD	Defined in input as ZNPCOV.
LIST OF % CHORD	Defined in input as PCTCHD.
NO. OUT STATIONS	Defined in input as ZNIS.
LIST - STATIONS	Defined in input as ZBLDST.

LSTPARMS:

Selecting the debug option, LSTBUG = 1, will print additional input definition as shown in Figure 16, which lists the available input options, their location number and the selected or defaulted values. Refer to the input description for more detail on input items. This is repeated for both rotors of a counter-rotation Prop-Fan.

NOIZPARM:

The debug option of 1 will print the page shown in Figure 17, which shows the input parameters, defined in the input section.

VELGRADS:

The debug option of 1 will result in the printout shown in Figure 18. Note that this input is not from the same test case as most of the other output sections and the positions and velocities are not normalized.

VORTPARM:

The debug option of 1 will print the page shown in Figure 19, which shows the input parameters, defined in the input section. The form of the VORTPARM output is identical for both the front and rear rotor in counter-rotation cases. Values of "X FOR LEV ACTION" are the chordwise positions (VTXDLX) at which the vortex loads act (see inputs).

WAKEPARM:

For counter-rotation operation, no items should be entered under the WAKEPARMS command: this description is superfluous. For single rotation, the printout in Figure 20 will be obtained. The input parameters are defined in the input section.

INTERPRM:

If the debug parameter for INTERPRM is set to 1, the output in Figure 21 results. The input parameters are defined in the input section. The following table relates the input and output designations.

<u>OUTPUT ITEM</u>	<u>CORRESPONDING INPUT ITEM</u>
Debug Switch	INTBUG
K	INTXK
Z0	INTZ0
ZNORM	INTZNM
AOPT	INTAPT
IVWK	INTVWK
FPHW	INTFPH
NPSKN	INTSKN
TOL	INTTOL
TOLI	INTOLI
MMI	INTMMI
IPLOT	INTPLT
IPRT	INTPRT

Aerodynamic Output

AEROEXEC:

Figures 22 through 28 show the printout when LSTPARMS and CRPPARMS debug variables are set to one. Figure 22 shows the output for the GETXMB routine, which calculates the locations of the control points on each rotor relative to the other. This routine prints out seven blocks of information: some general propeller information, the geometry information for the forward rotor, the location of the forward rotor control points relative to the rear rotor, the forward rotor leading edge sweep information, the geometry for the rear rotor, the location of the rear rotor control points relative to the forward rotor, and the rear rotor leading edge sweep information.

Figure 23 shows the blade description. MCA and FA are shown in Figure 24. These describe the location, in space, of the mid chord line of the blade.

Figure 25 shows the locations of the front row control points relative to the pitch change axis of the rear rotor. DELTA PHI is the angle measured from the helicoidal surface to the control point. XMBAR is the distance, parallel to the axis of rotation, from the pitch change axis to the control point. MBAR is the control point number at a given radius. MU is the control point number counting from the forward control point at the root to the aft-most at the tip.

Figure 26 is the list of forward rotor inner and outer wake points. The inner wake points are those within a circular cylinder defined by the tips of the rear rotor. Outer wake points would be outside this cylinder.

Figure 27 is output of the LESWP routine, which calculates leading edge sweep. The sweep angle is shown in degrees at the stations specified by ZNIS and ZBLDST in the BLADEGEO inputs.

Figure 28 is the list of rear rotor inner and outer wake points. The inner wake points are those within a circular cylinder defined by the tips of the forward rotor. Outer wake points would be outside this cylinder.

Figure 29 shows the re-mapping of each rotor's control points, relative to the other rotor assuming the upstream influence follows streamlines. Since no data were entered under VELGRADS in this case, the default number of 5 streamlines (4 streamtubes) is used, the streamlines are concentric cylinders and the re-mapping does not move anything. Note that the first control radius is below the spinner cut-off, and therefore outside the inner streamtube (thus has the null streamtube 0 assigned to it), and that the outer 4 control radii are all contained in the outer streamtube (streamtube 4).

Figure 30 shows the information passed to the lifting surface solver (F271). This is:

<u>PARAMETER</u>	<u>DESCRIPTION</u>
TEMP, DEGF	Ambient temperature, °F
RHO/RHO STD	Ambient density/standard density
SPEED OF SOUND	Ambient speed of sound, fps
ADVANCE RATIO	V/nD , where V is flight velocity, in fps, n is propeller rotation rate in revolutions/second, and D is diameter, in feet.
FLIGHT MACH NO.	Flight Mach number
FLIGHT SPD KTS	Flight velocity, knots (nautical miles per hour)
RPM	Propeller rate of rotation, rpm
TIP HEL. MACH	Mach number based on resultant of flight and tip speeds.
START BLENDING	Defined in LSTPARMS input as QMBLEN
DIAMETER	Propeller diameter, feet
NO. BLADES	Number of blades
NO. INPT STA.	Number of input stations
FREQ. OF UNST.	Defined in LSTPARMS input as QQ
NO. NODAL DIA.	Defined in LSTPARMS input as QK
K - DOWN	Defined in LSTPARMS input as QKDOWN
K - START	Defined in LSTPARMS input as QKSTART
INPUT STATIONS	Blade radial station/blade tip radius
B/D	Blade chord/propeller diameter
TOTAL TWIST	Operating twist from plane of rotation, degrees
MCA/D	Distance from pitch change axis to blade mid-chord point along the helix/propeller diameter, see Figure 24. This and FA/D

(next item) are functions of blade geometry and advance ratio.

FA/D	Perpendicular distance from helix to the intersection of the blade mid-chord and mid-camber point/diameter, see Figure 24.
T/B	Maximum blade thickness/blade chord
CLD	Blade design lift coefficient
SWEEP	Sweep angle between mid-chord line and resultant inflow velocity

LST CAMBER TABLE:

Another output table is shown in Figure 31. This is a table of the blade camber angle, measured from the plane of rotation as a function of local blade radius (normalized by tip radius) and fraction of the local chord.

ANSO:

Figure 32 gives the initial output from subroutine ANSO. This includes the contributors to the velocity triangle at each radial station and each control point. There are eleven columns; they are describe below.

Parameter	Description
I,MBAR, MU	Indexing information. I is station number, counting from root; MBAR is control point number, counting from leading edge of blade. MU is control point index, counting from leading edge to trailing edge, from root to tip.
R/R	Radial location of station in terms of R/R_{tip} .
TH+CAMB	Angle from plane of rotation to camber surface of the blade at this location, measured in degrees.

THICKNESS

W_T , thickness vector or the contribution to turning due to airfoil thickness, measured in degrees. In this case the W_T could not be calculated due to numerical problems on the IBM 3090. Typically the magnitude of this is less than 2°.

V-AXIAL

Axial component of the local change in velocity, $\Delta V/V_o$, due to induced flow and the presence of another rotor. This will be zero for the first pass for the forward rotor.

V-SWIRL

Tangential component of the local change in velocity, $\Delta V/V_o$, due to induced flow and the presence of another rotor. This will be zero for the first pass through the forward rotor.

PI*X/J

$\pi \cdot (r/R_{up})/J$, the tangent of the advance angle at each radial station.

CENTER BODY

The local change in velocity due to the presence of the center body; this is from the velocity field which has been entered via the VELGRADS command. This is zero as no velocities were entered via the VELGRADS command.

WMU

Turning required to ensure the flow is tangent to the camber surface.

Also printed here is the coefficient of sound power, which is:

$$\text{acoustic power loss}/(\text{density} \cdot (\text{rev/unit time})^3 \cdot (\text{diam})^5)$$

PERFORMANCE RESULTS:

Figure 33 shows the performance results for the individual rotor:

$$\begin{aligned} C_p &= P/\rho n^3 D^5 \\ C_t &= T/\rho n^2 D^4 \\ \text{Efficiency} &= J(C_t/C_p) \end{aligned}$$

where n is rotor rotational speed
 D is diameter
 ρ is fluid density
 P is power
 T is thrust

The units of n, D, and ρ , P, and T must be consistent.

Included are potential loads plus profile drag losses and the various non-linear lift terms which may result from leading edge sweep.

VORTEX CALC.:

Figures 34 through 38 show the vortex calculation outputs. Figure 34 shows the operating conditions. Figure 35 shows the angle of attack (A.O.A) at the leading edge, three dimensional angle, (ALPHA 3-D), induced angle, advance angle, and blade angle. Figure 36 shows the coefficients from the potential calculations. CDPOT does not include leading edge thrust. L.E. K, MAG is the leading edge suction force coefficient. This is calculated within the lifting surface portion of the code. It is used to calculate the leading edge force coefficient. Figure 37 shows the lift and drag coefficients which result from the vortex calculations. The incremental lift and drag coefficients illustrate the relative magnitude of the vortex components. Note that the tip edge vortex can cause lift (separated flow) or radial forces (attached flow). The terms "TIP VORTEX" and "SE VORTEX" (side edge) are used interchangeably. Figure 38 shows the elemental performance. MODOPT and NBOPT are LSTPARMS inputs and are explained in the LSTPARMS input section.

PERFORMANCE RESULTS:

Figure 39 shows the performance of each individual rotor. CP is the standard propeller power coefficient, $CP = P / (\rho n^3 D^5)$. CT is the standard propeller thrust coefficient, $CT = T / (\rho n^2 D^4)$. This information is repeated for each pass through each rotor.

INTERFERS:

Figure 40 shows the velocities calculated as a result of the steady interference between rotors. The first section is a tabulation of the change in axial velocity due to the center body (VX-BODY), which is zero for this case as no velocities were entered with the VELGRADS command, and the rotor's induced velocity. VX-POT is the change in axial velocity, $\Delta V_i / V_0$ due to potential flow. VX-2DARY is the increment due to non-potential loading, e.g., vortex flow. The second section shows the velocity increment due to rotor loading at the rear rotor control points.

PRTPRF:

Figure 41 shows the performance summary at one of the intermediate steps. In part A of this Figure the performance without the vortex loading is shown, in part B the performance with the vortex loading. Both parts are divided into two sections: a coefficient section and a ratio section. In the coefficient section, the power, thrust, and torque coefficient and the efficiency are shown. The last coefficient, ROLLING MOMENT, is defined as

$$C_{rm} = (Q_{fwd} - Q_{aft}) (\rho n^2 D^5)$$

where Q_{fwd} and Q_{aft} are the forward and rear rotor torque, respectively. All coefficients in the "TOTAL" column are based on the diameter and rotation rate of the forward rotor, hence FWD + AFT do not equal TOTAL. The ratio section has the ratio of tip speed, diameter, and angular speed of the aft rotor to the forward rotor. Also given are ratios of area, power, thrust, and torque for forward rotor to total, aft rotor to total, and aft rotor to forward rotor.

ADJUST:

Figure 42 shows the output of the routine which performs streamline adjustment. The first section shows the axial velocities at each control point. The second section shows the flow rates through each stream tube. The third section shows the new boundaries to the stream tubes after continuity is enforced.

CPMAP:

Figure 43 shows the re-location of the control points which are used for calculation of the flow induced by the rear rotor on the forward rotor.

CPMAP:

Figure 44 shows the relocation of the control points which are used for the calculation of the wake flow from the front rotor upon the rear rotor.

The output produced for each iteration is not included here; there is about 26 pages of printout per iteration with the DEBUG variable set to 1 in all input sections. Due to volume, they are not included here.

PROPELLER EFFICIENCY PROGRAM:

Figure 45 and 46 present the rotor-to-rotor interference field calculated by the near wake module. The information in Figure 45 is the steady calculation. At each station, there are two sets of data. The first is a single line with:

STATION

Station number, (1 = innermost) radial location in terms of R_{tip} of radius gener-

	ating influence field (here, the forward rotor)
PHI	Advance angle, degrees
SIGMA1	Internally calculated values used in
SIGMA2	calculations of wake velocities which
SIGMA1/SIGMA2	depend on radius and operating condition
TWIST	Angle between chordline and plane of rotation

Next there are ten lines (One line for each of QNCP points at each radius)

MBAR	Chord-wise control point number
XMBAR	Axial distance from pitch change axis, normalized by tip radius of rotor generating influence field
WMU (STEADY)	Perturbation angle produced by field
DOWN WASH	Down wash component of WMU
CHORDWISE	Chord-wise component of WMU
VISCOUS WAKE	Portion of WMU produced by the viscous deficit caused by profile drag of the front rotor
AXIAL	Axial component of WMU
SWIRL	Swirl component of WMU

Figure 46 shows a sample printout for the higher harmonic portion of the rotor-to-rotor interference field.

The first five lines show:

Direction of interference
Harmonic of blade pass frequency, m
Number of blades, B
Harmonic of shaft frequency, described in Section IV, "Input Description", under LSTPARMS as QK, and calculated as:

$$K_{front} = m * B_{aft}$$

$$K_{aft} = m * B_{front}$$

Q-order, described in Section IV, "Input Description", under LSTPARMS as QQ, and calculated as:

$$Q_{front} = K_{front} - (1 + (n_{front}/n_{aft}))$$

$$Q_{aft} = K_{aft} - (1 + (n_{aft}/n_{front}))$$

K and Q are calculated for the rotor receiving the interference.

Next, is one line for information for items which are constant at a given radius:

STATION	Station number and distance from center of rotation normalized by R_{tip} .
WAKEPNT	This is the normalized contracted radius for this station.
PHI	Advance Angle, degrees.
SIGMA1, SIGMA2, SIGMA1/SIGMA2	Internally calculated values used for calculations in the wake. These depend on radius and operating condition.
TWIST	Angle between chordline and plane of rotation, degrees.

After the line for each radius, there is one line for each chordwise point (QNCP):

MBAR, MU	Indexing information.
XMBAR	Distance from pitch change axis of rotor generating interference field.
DPHI	Angle from helicoidal surface to control point, degrees.
WMU	Unsteady loading downwash vector. This is the QWMU value described under LSTPARMS in Section IV, "Input Description".
DOWNWASH	Component of WMU normal to camber line of blade at this radial station.
CHORDWISE	Component of WMU tangent to chordline at this radial station.
VISCOUS WAKE	Component of WMU due to viscous wake.

VI. Noise Outputs

NOZOUT:

The first page of the noise program output (see Figure 47) summarizes the observer positions selected by the user. The first few lines repeat the header information. Then, the computer time used is presented. Then, the observer locations selected by the user are printed. First, the sideline distance for the front (or single) and/or rear rotors is printed. Then, for the front rotor, the retarded axial positions, the visual axial positions, and the corresponding retarded and visual radiation angles are printed. The relationships between the visual and retarded distances and angles are also shown in Figure 47. Finally, the front rotor azimuthal observer angle is printed.

The rear rotor is offset axially from the front rotor by a fraction of the front rotor radius. This fraction is printed, and the corresponding retarded and visual axial positions and radiation angles are printed. Listing of the rear rotor azimuthal observer position completes the observer geometry printout in figure 47.

The local ambient conditions are then listed, giving the temperature, ambient pressure normalized by sea level standard, and local speed of sound.

On the next page, in Figure 48, the front and rear rotor operating conditions are printed. FLIGHT MACH NUMBER is the free-stream Mach number. TIP ROTATIONAL MACH is the tip speed divided by the speed of sound. TIP RELATIVE MACH NUMBER is the resultant of the flight and tip rotational Mach numbers. MT/MX is the ratio of tip Mach number to flight Mach number. BPF is the blade passing frequency, measured in Hertz. The FOOT DIAMETER is tip diameter, in feet, of the rotor.

On the next page (Figure 49) is a header indicating the beginning of the noise calculation results. Following the header is a summary of the noise calculation results for the first directivity. This type of page is repeated for as many directivities as were requested by the user. The X POSITION ANGLE for visual and retarded axial position and angles for front and rear rotor is shown. Then, for each possible noise radiation frequency, a summary of the noise radiated by the front and rear rotors is given. The M COUNTER and K COUNTER are given for the front rotor. Thus, K COUNTER = 0 corresponds to steady loading, and the steady sources are also printed. The roles of the M COUNTER and K COUNTER are reversed for the rear rotor, so M COUNTER = 0 corresponds to steady loading for the rear rotor. Results are presented for each harmonic up to MMAX, and then a new page (not shown) presents results for the next axial observer location.

Finally, a summary of the total noise at each frequency is presented in Figure 50. The header information is followed by a listing of the observer coordinates. The computed radiation frequency and the total combined noise for the front and rear rotors are presented at each frequency. This output format is repeated for all requested directivities and harmonics.

VII. Program Installation

UCAP is written in FORTRAN-77, mostly adhering to ANSI X3.9-1978, with the common additions of the double precision complex (complex*16) data type and the IMAG intrinsic function. UCAP requires the IMSL Libraries, version 1.1 (formerly IMSL 10), mostly for FFT's, Bessel functions, and matrix inversions. The IMSL Libraries are copyrighted; they are not supplied with UCAP. A list of the routines directly called from UCAP is provided in Table II.

The target operating environments for this program are the Cray series of super-computers. This program was developed on an IBM 3090 running MVS/XA and a Sun workstation running Sun's version of UNIX. Based on experience with the interim (Task 2) version of UCAP and with UAAP, this program is expected to be operated on the Cray with double precision turned off (by a compiler option) and with the single precision version of the IMSL routines. Many complex numbers are operated on within UCAP; Table III presents a list of subprograms where AIMAG or IMAG is used. In the IBM and Sun dialects of FORTRAN-77, the IMAG intrinsic function is required when operating on complex*16 data. This is replaced by AIMAG for Cray FORTRAN, which does not support the complex*16 data type. Because of the different IMSL calls and the need to use AIMAG, directives for cpp (the C pre-processor, a utility supported by UNICOS and most UNIX systems) were included into the distribution source code to select single precision IMSL calls and AIMAG on Cray systems versus double precision IMSL calls and IMAG on other systems.

On Cray systems running UNICOS, selection of single/double precision IMSL subroutine calls and IMAG/AIMAG intrinsic function use would be done by compiling with:

```
cf77 -DCRAY -c -dp ucap.F
```

if the FORTRAN compiler supports the C pre-processor or

```
cpp -DCRAY ucap.F > ucap.f  
cf77 -dp -c ucap.f
```

where the FORTRAN compiler does not.

On Cray systems, *segldr* would then be used to link the resulting object code (ucap.o) with the IMSL Libraries in order to produce an executable copy of the program.

VIII. File Requirements

UCAP requires several files for input, output, and data transfer. The input data file (number 5), and the input data files for the noise routines (numbers 49 and 50) are fixed record length files. These must have a minimum of 80 characters per record, excluding the new line or carriage return used to terminate lines in the UNIX system; these will have to be padded with blanks. The input data files for the noise routines generated by UCAP are properly formed for program operation.

File Number	File Contents	File Remarks
5	Input Data	Fixed record length, with a minimum of 80 characters per record. A typical input file will contain about 400 lines (32,000 bytes).
6	Printed Output	Standard FORTRAN printed output: up to 133 characters per record, with the first character reserved for carriage control. This will be about 10000 lines.

The following files are generated by the program:

11	Copy of Input Data	Fixed record length, 80 characters per record. This is a "scratch" file which need not be retained after program execution. This will be the same size as file used for unit number 5.
40	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).
41	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).

49	Aft Rotor Input Data for Noise Routines	Fixed record length, 80 characters per record. This will be about 400 lines for the steady and 200 additional lines for each harmonic specified in CRPPARMS.
50	Forward Rotor Input Data for Noise Routines.	Fixed record length, 80 characters per record. This will be about 400 lines for the steady and 200 additional lines for each harmonic specified in CRPPARMS.
51	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).
52	Internal Storage	"Scratch" file for internal use. This must be about eight million bytes (one million Cray words).
AFTTHV	Aft Rotor Thick- ness Vector	Unformatted, i.e., written without FORTRAN format control. These may be saved for later use. Size is about 800 bytes (100 Cray words).
FWDTHV	Forward Rotor Thickness Vector	
SRPTHV	Single Rotor Thickness Vector	

Due to the necessity of generating numerous influence coefficient matrices, UCAP uses the FORTRAN OPEN statement to assign file names at run time, when running counter-rotation. Any influence coefficient matrix file may be retained for use in later program runs. However for counter-rotation the program must re-generate all influence coefficient matrices for a given rotor if any new influence coefficient matrix is required for that rotor.

File Name	File Contents	File Remarks
SRP000	Single rotation influence coefficient matrix. This is used for steady and unsteady matrices.	Unformatted. Approximately 20,000 Cray words (160,000 bytes).
AFT000 FWD000	Counter-rotation steady influence coefficient matrices, for the aft or forward rotor.	Unformatted. Approximately 20,000 Cray words (160,000 bytes) each.

AFT001 through
AFT0nn

Counter-rotation unsteady influence coefficient matrices, for the aft rotor. The trailing number (0nn) is incremented by one for each unsteady matrix required for the number of interaction orders (forward to rear rotor) specified in CRPPARMS.

Unformatted. Each is approximately 20,000 Cray words (160,000 bytes) each.

FWD001 through
FWD0nn

Counter-rotation unsteady influence coefficient matrices, for the forward rotor. The trailing number (0nn) is incremented by one for each unsteady matrix required for the number of interaction orders (forward to rear rotor) specified in CRPPARMS.

Unformatted. Each is approximately 20,000 Cray words (160,000 bytes) each.

IX. Error Messages

This section contains a description of the printed error messages, along with possible causes and remedies in alphabetized order.

"AIRFOIL NO. = ... OFF AIRFOIL DATA AND IOFF ..."

The program obtains profile drag from airfoil data tables as a function of lift, mach number, airfoil thickness ratio, and airfoil chord. This message indicates one or more of the above parameters exceeded the limits of the stored data.

Recommendation : check the output for reasonable values of drag coefficients. Use AIRPARMS inputs CDMULT and DCD to correct unreasonable values.

"AIRFOIL ... OFF AIRFOIL DATA "

Same as above.

"BDSO ... "

There are a number of errors, generally resulting in program termination, which are associated with the blade geometry generator; these messages are prefaced with BDSO. They arise because the blade surface generated from user input in BLADEGEO was not sufficient to allow intersection with the output stations (conical surfaces) specified in BLADEGEO variable ZBLDST.

Solution: The problem can usually be avoided (with only a slight loss in program accuracy) by setting THTDES = THTCUT in BLADEGEO, and assuring that $X(1) < ZBLDST(1)$ and $X(10) > ZBLDST(ZNIS)$ in BLADEGEO input.

"*** CONTROL POINT STATIONS NOT WITHIN ..."

The radial difference between control points, QZAR in LSTPARMS, and ZBLDST in BLADEGEO $> .02$.

Solution : Change the either QZAR or ZBLDST input values.

"FAILED TO CONVERGE ON CL ..."

An iteration failed when trying to obtain the profile drag data from the airfoil tables.

Recommendation : check the output for reasonable values of drag coefficients. Use AIRPARMS inputs CDMULT and DCD to correct unreasonable values.

"FOR OUTPUT POINT NUMBER ..."

Interpolation of the flowfield from VELGRADS is performed in two ways : radial first, axial second, and then axial first, radial second. Usually these interpolations yield the same value of velocity at a fixed radial and axial location. However, for this point the difference in interpolations exceeded 1 %. Probable cause : the flowfield is not smooth in either or both the radial and axial directions.

"FOR OUTPUT POINT NUMBER ... THE AXIAL ..."

The axial extent of coordinates input into VELGRADS was not sufficient to allow interpolation of the flowfield at either the blade leading or trailing edge.

Solution: add more points to the flowfield input in VELGRADS in the axial direction.

"FOR OUTPUT POINT NUMBER ... THE RADIAL ..."

The radial extent of coordinates input into VELGRADS was not sufficient to allow interpolation of the flowfield at either the blade root or tip.

Solution : add more points to the flowfield input in VELGRADS in the radial direction.

"INVALID INPUT CHARACTER ..."

The load routine has found a character in column 1 which is not an "L", "C", "E", or blank.

Possible causes : "END" record omitted; numeric data in column 1.

"THE INPUT CONTAINS AN UNKNOWN COMMAND ... "

A COMMAND was expected at this point in the input, however, the 8 printed characters do not represent a recognizable command.

Possible causes : misspelled command; no "END" record in load format, incorrect case (use UPPER CASE only); COMMAND didn't start in column 1.

"THE INPUT CONTAINS AN UNKNOWN SUBCOMMAND.."

A sub-command was found which didn't match the acceptable sub-commands.

Possible causes : incorrect spelling; incorrect placement of parenthesis.

"THE NUMBER OF HEADER CARDS"

More than 10 header records were encountered during processing of the HEADER command.

Possible causes : more than 10 records following the HEADER command; no "END" record after the last header record.

"V1S1X1 DIMENSIONED 20X20 ..."

The flowfield input in VELGRADS was too large; the maximum number of coordinates in the axial or radial direction is 20.

Solution : reduce the number VINRD and/or VINAS to 20.

"***** MM2 AND MM3 MUST BE LESS THAN 100 ..."

See QMM2 and QMM3 limits in LSTPARMS.

"***** NBOPT MUST BE 1 OR 2 ..."

See QNBOPT limits in LSTPARMS.

"***** NCP GREATER THAN MAX NCP ..."

See QNCN limits in LSTPARMS.

"***** NIS GREATER THAN MAX NIS ... "

See ZNIS limits in BLADEGEO.

"** NOIZEXEC CALLED WITH KEYWORD ..."

An unrecognizable sub-command was found. The sub-command must be "EXECCASE".

"***** NSM GREATER THAN MAX NSM ... "

See QNSM limits in LSTPARMS.

"***** NSM * NCP GREATER THAN ..."

Ensure that QNSM * QNCP < 1000 in LSTPARMS.

"*** NUMBER OF NODAL DIAMETERS (K) MUST ..."

If QQ = 0 then QK must equal zero in the LSTPARMS input.

"***** NX GREATER THAN ..."

See ZNPCOV limits in BLADEGEO.

"***** THE DATA FOR THIS RUN & THE DATA ..."

A label is attached to the "K-INVERSE" matrix describing the parameters used to create it. The current value of the input variable listed below the error message does not agree with that in the attached label.

Cause : This generally arises because a "K-INVERSE" matrix from a previous run was used as input to this run (see QPART1 in LSTPARMS) and the data used to generate that matrix is different than that being used to run the current case.

"*** THE NO. OF DIRECTIVITY POINTS ..."

See ZNX limits in NOIZPARM.

"*** THE NO. OF HARMONICS IS GREATER ..."
See ZMMAX limits in NOIZPARM.

"*** THE NO. OF HARMONICS IS GREATER THAN ALLOWED 150"

"*** THE NO. OF HARMONICS X THE NO. OF BLADES IS LIMITED TO
1000"

"*** THE NO. OF RADIAL INTEGRATION POINTS IS LIMITED TO 2000"

"*** THE NO. OF DIRECTIVITY POINTS IS LIMITED TO 20"

Cause - input values larger than permissible
Solution - correct input

References

1. Hanson, D.B., "Unified Aeroacoustics Analysis for High-speed Turboprop Aerodynamics and Noise: Volume I - Development of Theory for Blade Loading, Wakes, and Noise", NASA Contractor Report 4329, 1991
2. Hanson, D.B. et al "Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise: Volume III - Application of Theory for Blade Loading Wakes, Noise, and Wing Shielding", NASA Contractor Report 184193, 1991
3. Menthe, R.W., McColgan, C.J. and Ladden, R.M., "Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise: Volume IV - Computer User's Manual for UAAP Turboprop Aeroacoustic Code", NASA Contractor Report 185194, 1991

Appendix A

Example QWMU Generating Program and Modified Block Data CRPBLK

This section has the listing (Figure 51) for a small, stand alone program, QWMUGEN, which will generate the unsteady downwash vector, QWMU, described under LSTPARMS (locations 351 to 550) in the section of this manual describing the inputs.

This program will generate the QWMU vector for sinusoidal gust described in Reference 1, pp 88-90. It requires these inputs:

J, advance ratio

NCP, number of chordwise panels (LSTPARMS, location 2)

NSM, number of spanwise modes (LSTPARMS, location 4)

QZAR, spanwise locations of control point radii (LSTPARMS, locations)

BD, blade chord/diameter at the QZAR points

QQ, order of unsteady loading harmonic (LSTPARMS, location 21)

WZERO, peak amplitude of gust velocity divided by rotor tip speed

This program will print the elements of the QWMU vector, in a form suitable for use in the LSTPARMS section of the input.

The second listing (Figure 52) is the block data, CRPBLK, in which the default values for the items described under the CRPPARMS input section are set. This listing has the default value of CRPTOL (CRPPARMS, location 5) set to 0.01. The default values of the other variables can also be set to different values here.

Table I
Common block locations

Common Block Name	Size in bytes	subprogram {type}
airalz	2364	airbk3 {block data} air24 {subroutine} airdrg {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}
aircdf	312	airbk2 {block data} air24 {subroutine} airdrg {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}
aircdm	392	airbk3 {block data} air24 {subroutine} airdrg {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}

Table I (continued)

airdat	4000	air24 {subroutine} airdgr {subroutine} airflx {subroutine} airoff {subroutine} airp02 {subroutine} casarf {subroutine} drag24 {subroutine} isoafl {subroutine} isoarf {subroutine} lift24 {subroutine} swparf {subroutine} zeroal {subroutine}
airp01	400	airbk1 {block data} airdrg {subroutine} airprm {subroutine} lstuns {subroutine}
bdsc01	644	bds018 {subroutine} bldbk3 {block data}
bdsc02	8	bds018 {subroutine}
bdsc03	3628	bds014 {subroutine} bldbk4 {block data}
besar	6400000	bessav {subroutine} bsint {subroutine} bsjint {subroutine} bsyint {subroutine}
besdel	8	bessav {subroutine} bsint {subroutine} bsjint {subroutine} bsyint {subroutine}
bldg01	4000	bldbk {block data} bldct1 {subroutine} bldgi1 {subroutine} fetch {subroutine} retrev {function} store {subroutine}
bldg02	8000	fetch {subroutine} retrev {function} store {subroutine}

Table I (continued)

bldg03	60800	bldct3 {subroutine} bldgi3 {subroutine} fetch {subroutine} retrev {function} store {subroutine}
bldgc3	121600	fetch {subroutine} store {subroutine}
bldgeo	24000	bldbk2 {block data} bldct1 {subroutine} bldct3 {subroutine} bldgi1 {subroutine} bldgi2 {subroutine} bldgi3 {subroutine} bldgp1 {subroutine} fetch {subroutine} lstuns {subroutine} mcafa {subroutine} retrev {function} store {subroutine}
bldgx0	48000	fetch {subroutine} retrev {function} store {subroutine}
com002	72	ggs011 {subroutine} ggs107 {subroutine}
crpp01	36	crpblk {block data} crpprm {subroutine} lstuns {subroutine} lstvvc {subroutine} newpg1 {subroutine} nrk001 {subroutine} retrev {function} wak001 {subroutine}
crpsr1	24	velgrd {subroutine}
crpsr2	4	velgrd {subroutine}

Table I (continued)

dtetme	32	airprm {subroutine} bldgem {subroutine} bldgi1 {subroutine} bldgi2 {subroutine} bldgi3 {subroutine} bldgp1 {subroutine} hdrbk1 {block data} header {subroutine} inptrw {subroutine} intfr1 {subroutine} intprm {subroutine} lstctl {subroutine} lstprm {subroutine} lstuns {subroutine} MAIN {main routine} newpg1 {subroutine} noisez {subroutine} runprm {subroutine} vtxprm {subroutine} wak001 {subroutine} wakpr1 {subroutine} wakprm {subroutine}
hdr1	728	hdrbk2 {block data} header {subroutine} lstctl {subroutine} lstuns {subroutine} newpg1 {subroutine}
hdr2	4	hdrbk2 {block data} header {subroutine} lstctl {subroutine} lstuns {subroutine} newpg1 {subroutine}
hsqspl	4424	lstsw1 {subroutine} noznhf {subroutine} qsplin {subroutine} vtxinp {subroutine}
intp01	64	intblk {block data} intfrs {subroutine} intfr1 {subroutine} lstctl {subroutine} lstuns {subroutine}
kclsav	40	isoarf {subroutine}

Table I (continued)

lstp01	2800	fetch {subroutine} lstbk1 {block data} lstprm {subroutine} lstuns {subroutine} retrev {function} store {subroutine}
lstp02	5600	fetch {subroutine} retrev {function} store {subroutine}
lstr01	29800	airdrg {subroutine} fetch {subroutine} intrf1 {subroutine} lstuns {subroutine} lstvvc {subroutine} store {subroutine}
lstr02	4400	fetch {subroutine} intfr1 {subroutine} lstuns {subroutine} store {subroutine} wak001 {subroutine}
lstsr2	8800	fetch {subroutine} store {subroutine}
lstspr	59600	fetch {subroutine} store {subroutine}
nozdat	632	nozbk1 {block data} nozclc {subroutine} nozprm {subroutine}
nozs16	6408	nozbk2 {block data} nozffc {subroutine} noznfc {subroutine}
output	4	bds014 {subroutine}
provrs	4	idblk {block data} lstuns {subroutine} newpg1 {subroutine}
rnep01	400	lstctl {subroutine} lstuns {subroutine} mcafa {subroutine} runblk {block data} runprm {subroutine}

Table I (continued)

vliic1	4900	lstctl {subroutine} lstuns {subroutine} vel002 {subroutine} velblk {block data} velgrd {subroutine} vttbin {subroutine}
vtxc02	480	fetch {subroutine} retrev {function} store {subroutine}
vtxcom	240	fetch {subroutine} retrev {function} store {subroutine} vtxblk {block data} vtxout {subroutine} vtxprm {subroutine}
wakp01	4000	fetch {subroutine} lstuns {subroutine} retrev {function} store {subroutine} wak001 {subroutine} wakblk {block data} wakprm {subroutine}
wakp02	8000	fetch {subroutine} retrev {function} store {subroutine}
wakr01	24000	fetch {subroutine} intfr1 {subroutine} lstuns {subroutine} store {subroutine} wak001 {subroutine} wakpr1 {subroutine}
waksp2	48000	fetch {subroutine} store {subroutine}
work	2119852	f271 {subroutine} f271no {subroutine} intfr3 {subroutine} lstctl {subroutine} lstuns {subroutine} nrk001 {subroutine} wak003 {subroutine}
work1	3200	f271 {subroutine}

Table I (continued)

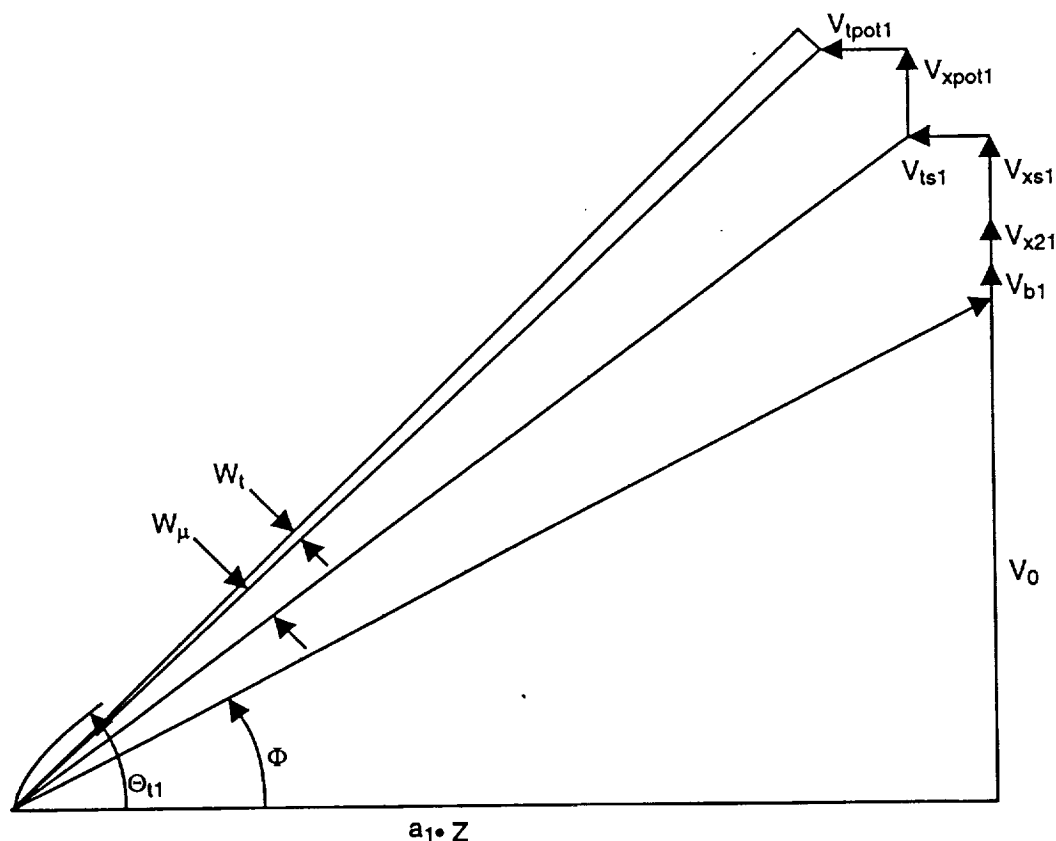
		f271no {subroutine}
		lstuns {subroutine}
worksp	100000	MAIN {main routine}
xindex	12	bds014 {subroutine}

Table II
Locations of IMSL routines used within UCAP

IMSL Routine	Used by
bsi0	ik0, iksub0, stdiki, sum3, sum4, tik0
bsi1	sum3
bsins	nozhnk, wake
bsj0	iksub0
bsj1	wingf
bsjns	bessav, bsint, bsjint, nozffc, nozhnk, noznfc
bsk0	ik0, iksub0, stdiki, sum3, sum4, tik0
bsk1	sum3, wingf
bskes	nozhnk, wake
bsys	bessav, bsint, bsyint, iksub0, nozhnk, wingf
csint	f001
csval	f001, ffun
ctime	jobtim
dtime	MAIN, endjob
erfc	imnsub, imnsin
fftcx	fftcx, fftcx0, fftcxn
iidex	fetch, retrev, store
iicrs	fetch, retrev, store
iwkin	MAIN
lincg	kmatrx
linrg	f271no, kmatr0
tdate	MAIN

Table III
Locations where AIMAG is used within UCAP

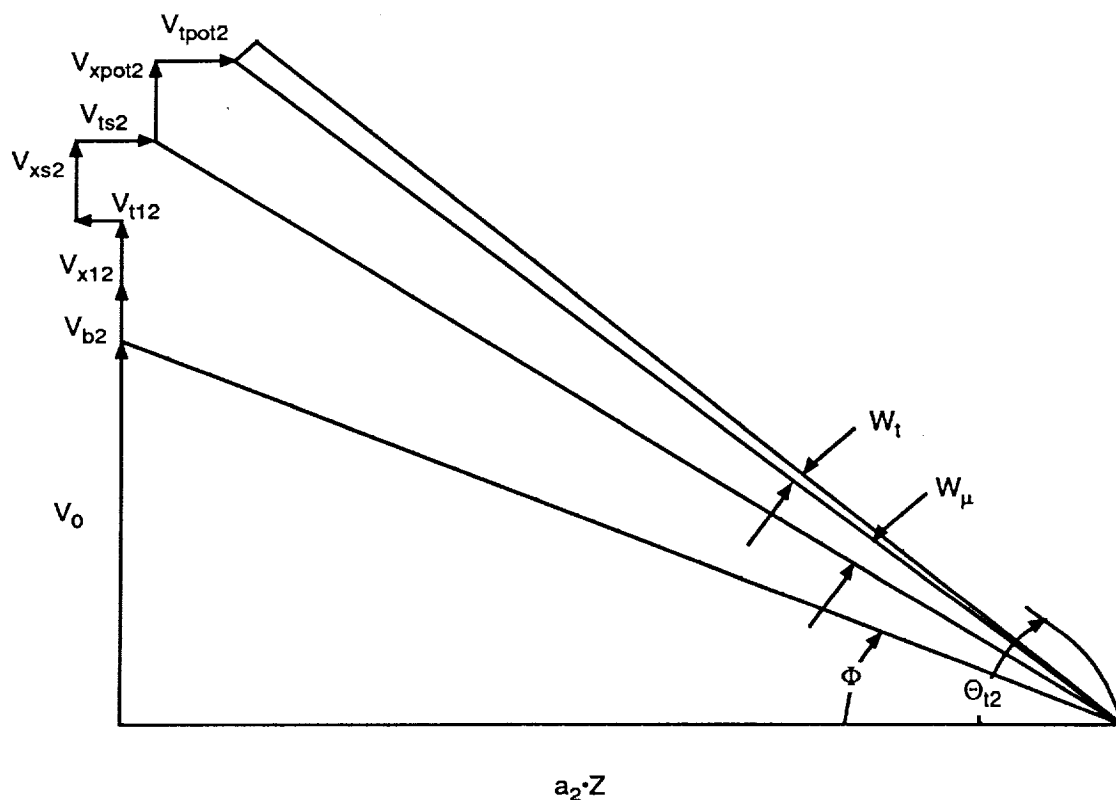
ansn1
bds024
bound
fftcxn
iksub
iksub0
lstctl
nozffc
noznj2
noznfc
noznj2
nozout
nozstt
nozunt
r4aray
wingf



- V_{xpot1} $\Delta V_x/V_0$ due to potential loading of forward rotor.
 V_{tpot1} V_t/V_0 due to potential loading of forward rotor.
 V_{ts1} V_t/V_0 due to secondary (non-potential) loading of forward rotor.
 V_{xs1} $\Delta V_x/V_0$ due to secondary (non-potential) loading of forward rotor.
 V_{x21} $\Delta V_x/V_0$ from rear rotor loading at forward rotor.
 V_{b1} $\Delta V_x/V_0$ due to presence of center body.
 V_0 Freestream velocity. Normalized freestream velocity is unity.
 $a_1 \cdot Z$ $(\pi/J_1) \cdot (r/R_1)$, where J is advance ratio, R_1 is tip radius, r is local radius.
 Φ Advance angle, measured from plane of rotation.
 Θ_{t1} Camber plus twist angle for each panel, measured from plane of rotation.
 W_t Turning due to blade thickness.
 W_μ Turning required for boundary condition (no flow through the blade) to be met.
 ΔV_x Change in axial velocity
 V_t Tangential (swirl) velocity

DG1217001ag

Figure 1 (part a) Forward Rotor Velocity Diagram



V_{xpot2}	$\Delta V_x/V_0$ due to potential loading of rear rotor.
V_{tpot2}	V_t/V_0 due to potential loading of rear rotor.
V_{ts2}	V_t/V_0 due to secondary (non-potential) loading of rear rotor.
V_{xs2}	$\Delta V_x/V_0$ due to secondary (non-potential) loading of rear rotor.
V_{x12}	$\Delta V_x/V_0$ from forward rotor loading at rear rotor.
V_{t12}	V_x/V_0 from forward rotor loading at rear rotor.
V_{b2}	$\Delta V_x/V_0$ due to presence of center body.
V_0	Freestream velocity. Normalized freestream velocity is unity.
$a_2 \cdot Z$	$(\pi/J_2) \cdot (r/R_2)$, where J is advance ratio, R_2 is tip radius, r is local radius.
Φ	Advance angle, measured from plane of rotation.
Θ_{t2}	Camber plus twist angle for each panel, measured from plane of rotation.
W_t	Turning due to blade thickness.
W_μ	Turning required for boundary condition (no flow through the blade) to be met.
ΔV_x	Change in axial velocity
V_t	Tangential (swirl) velocity

Figure 1 (part b) Rear Rotor Velocity Diagram

- A Calculate axisymmetric streamlines. This is done off line.
- B Calculate, off line, streamline angles where streamlines cross blade mid-chord line. These angles are measured from the axis of rotation.
- C Calculate table of camber plus twist angles, along conical surfaces defined by streamline angles calculated in step B, for front and rear rotors.
- D Calculate the location of the rear rotor control points in relation to stream tubes defined by the axisymmetric streamlines.
- E Calculate forward (or single) rotor influence coefficient matrix. Store for later use.
- F Calculate turning angle due to blade thickness for forward (or single) rotor. Store for later use.
- G Calculate potential loading. $L=[K]^{-1} \times W$, where $[K]^{-1}$ is influence coefficient matrix, and W is the turning angle required to satisfy the boundary conditions.
- H Calculate induced velocity from potential loading using momentum theory.
- J Calculate total loading, including vortex effects.
- K Calculate induced velocity from total loading, including vortex effects.
- L Calculate axial $\Delta V/V^\infty$ and swirl, V_θ/V_∞ at rear rotor mapping points, calculated in step D, above. These velocities will be applied at the rear rotor control points, as shown in Figure 1.

Steps M through V are only applied in counter-rotation. For single rotation, jump to step W.

- M Calculate locations of forward rotor control points relative to annular stream tubes defined by the axisymmetric streamlines.
- N Calculate rear rotor influence coefficient matrix. Store it for later use.
- P Calculate turning angle due to blade thickness.
- Q Calculate potential loading, as in step G, above.
- R Calculate induced velocity from potential loading, using momentum theory.
- S Calculate total loading, including vortex effects.
- T Calculate induced velocity field from total loading, including vortex effects.
- U Calculate axial $\Delta V/V_\infty$ induced by rear rotor at forward rotor mapping points, calculated in step M, above. Note there is no swirl ahead of a rotor.
- V Calculate synthetic streamline radial locations in order to enforce incompressible continuity, $\nabla \cdot \mathbf{v} = 0$.
- W Convergence monitor: converged if $|c_{p,i} - c_{p,i-1}|$ is less than a limiting value for both rotors.
- X Noise module: acoustic analysis

Figure 2: Conceptual flow chart of UCAP

==== TSO FOREGROUND HARDCOPY ==== 14:26:48 93112
 DSNAME=TSOG04F.TREE.DATA

```

MAIN
1  IMKIN
1  JOBTIM
1  DTIME
1  TDATE
1  INPTRW
2  NEWPG1
1  STORE
1  LSTCTL
2  SPZERO
2  SETIO
2  GETXMB
3  HCAFA
4  FETCH
4  NEWPG1
4  TOLSTS
4  PRNTXX
4  PRNTIN
4  LSTSWI
5  QSPLIN
6  SPFUNC
6  SPCDEF
7  SPLSD3
6  SPSVAL
7  SPLSEV
6  SPMVAL
7  SPLSEV
5  LSTCOA
5  LSTXVZ
4  STORE
3  UNLIN
3  LESWP
2  KINFIL
2  THVFIL
2  LSTDV
3  FETCH
3  NEWPG1
3  PRNTXX
3  F271NO
4  JOBTIM
4  EXIT
4  BLEND
5  DUNLIN
4  IMILU
4  MUNUAR
4  DLINRG
4  ANSONO
5  DUNLIN
5  DUNBAR
5  ANSONI
6  DUNLIN
6  IMILU
5  NEWPG1
5  UVINT
5  AIRDRG
6  AIRFLX
7  ISOARF
  
```

```

8  A
9  A
A  B
A  B
9  A
A  B
A  B
7  A
8  A
9  A
A  B
A  B
A  B
A  B
C  C
C  D
8  A
9  A
8  A
9  A
7  A
8  A
9  A
A  B
A  B
A  B
A  B
C  C
C  D
8  A
9  A
9  A
9  A
7  A
8  A
9  A
A  B
A  B
A  B
A  B
C  C
C  D
  
```

```

ISOARF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
AIROFF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
CASARF
ISOARF
ISOARF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
AIROFF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
STARC
UNINT
ZEROAL
ISOARF
ISOARF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
AIROFF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
DZROAL
UNBAR
UNINT
CLFACT
UNBAR
SWPARF
ISOARF
ISOARF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
AIROFF
AIR24
LIFT24
LNEAR1
DRAG24
LNEAR1
  
```

Figure 3A: UCAP Calling Tree

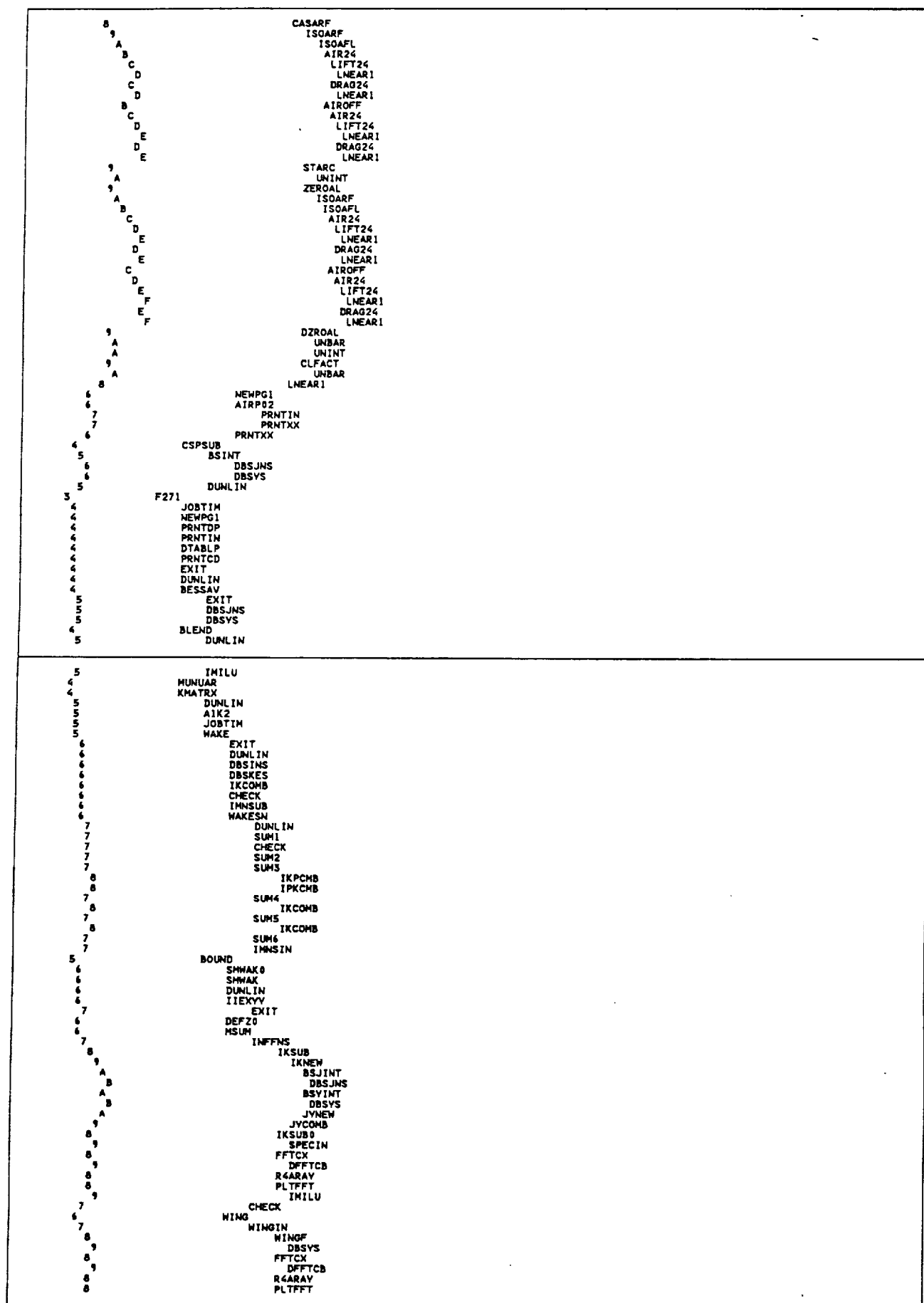


Figure 3A: UCAP Calling Tree (continued)

Figure 3A: UCAP Calling Tree (continued)

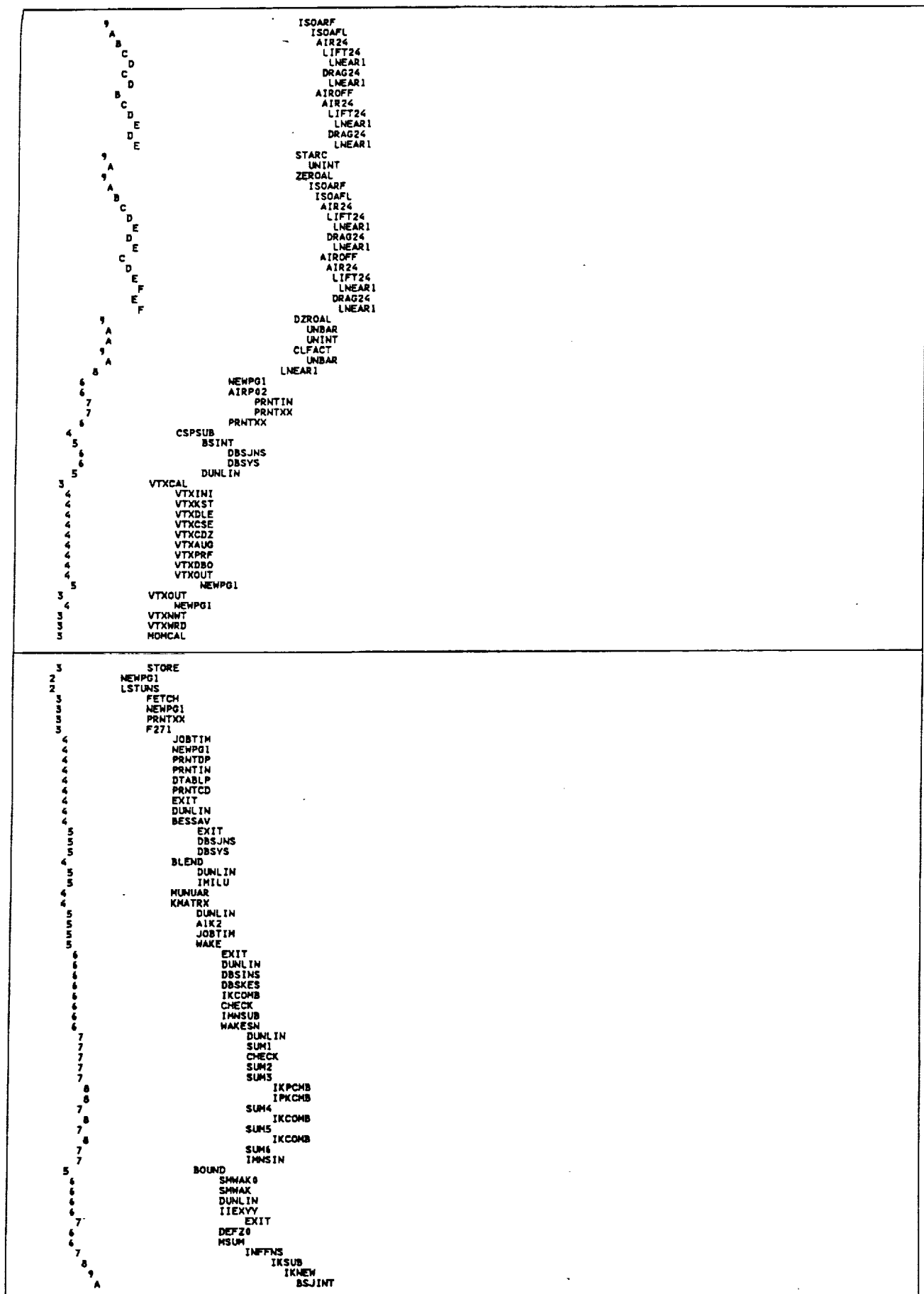


Figure 3A: UCAP Calling Tree (continued)

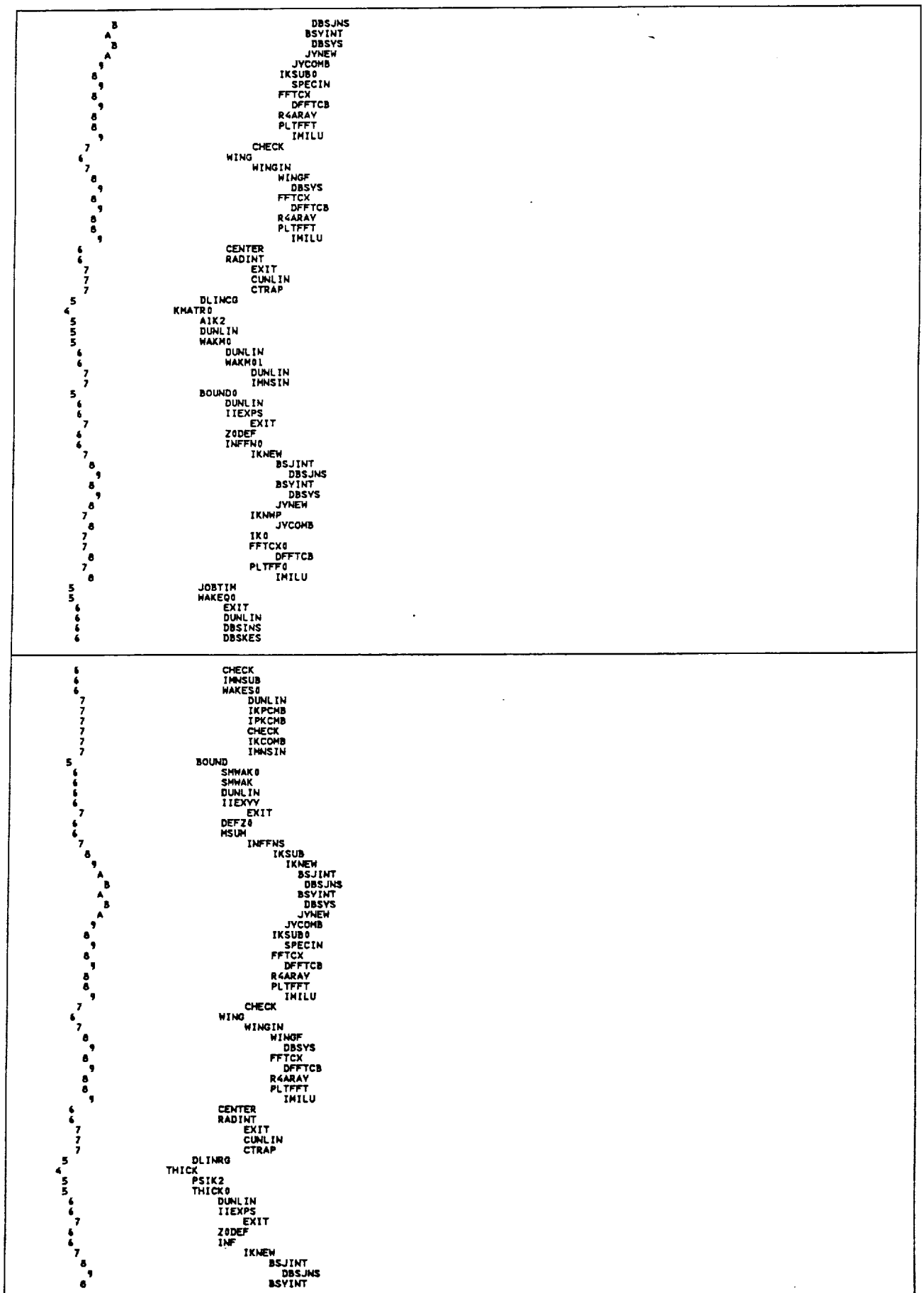


Figure 3A: UCAP Calling Tree (continued)

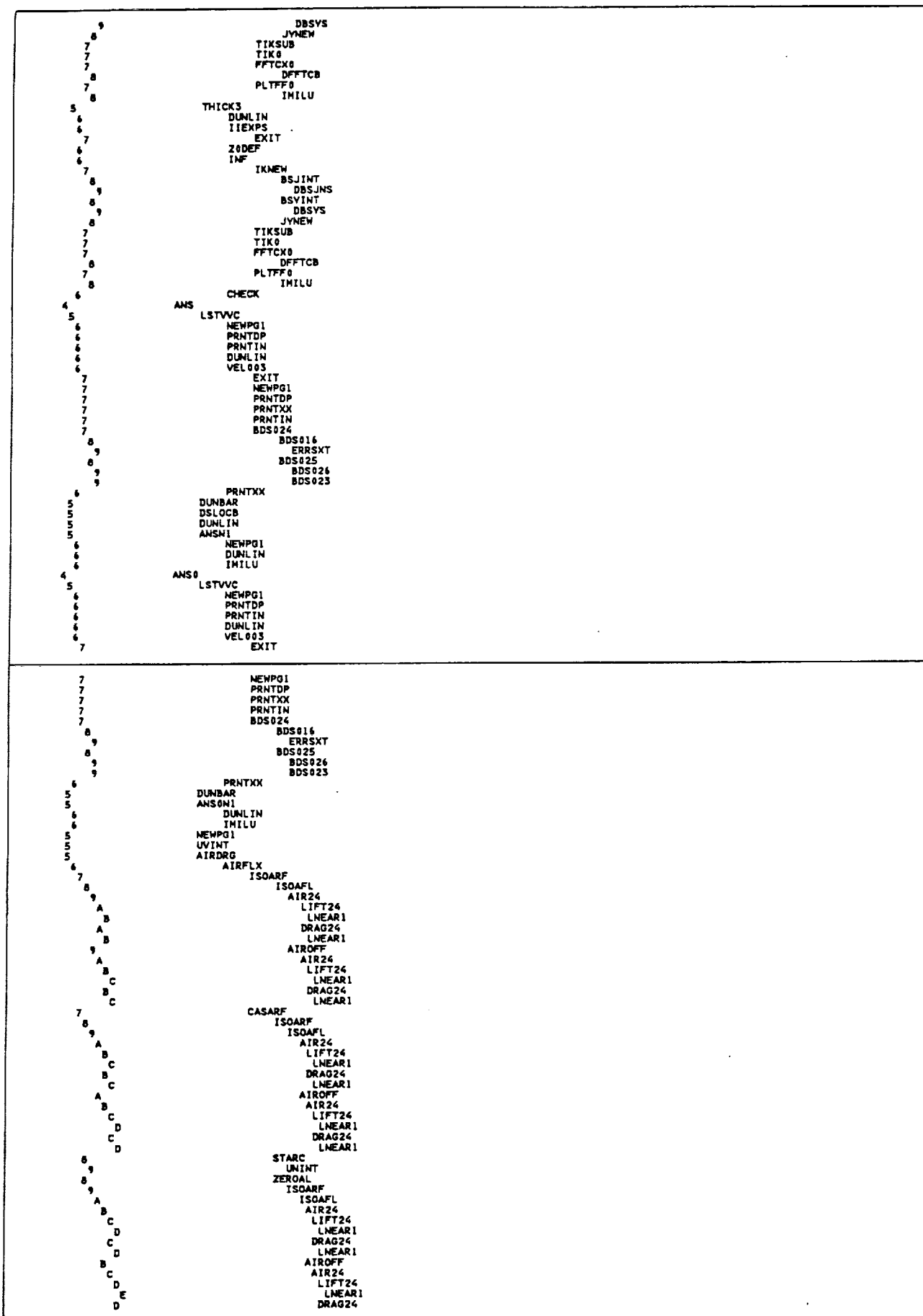


Figure 3A: UCAP Calling Tree (continued)

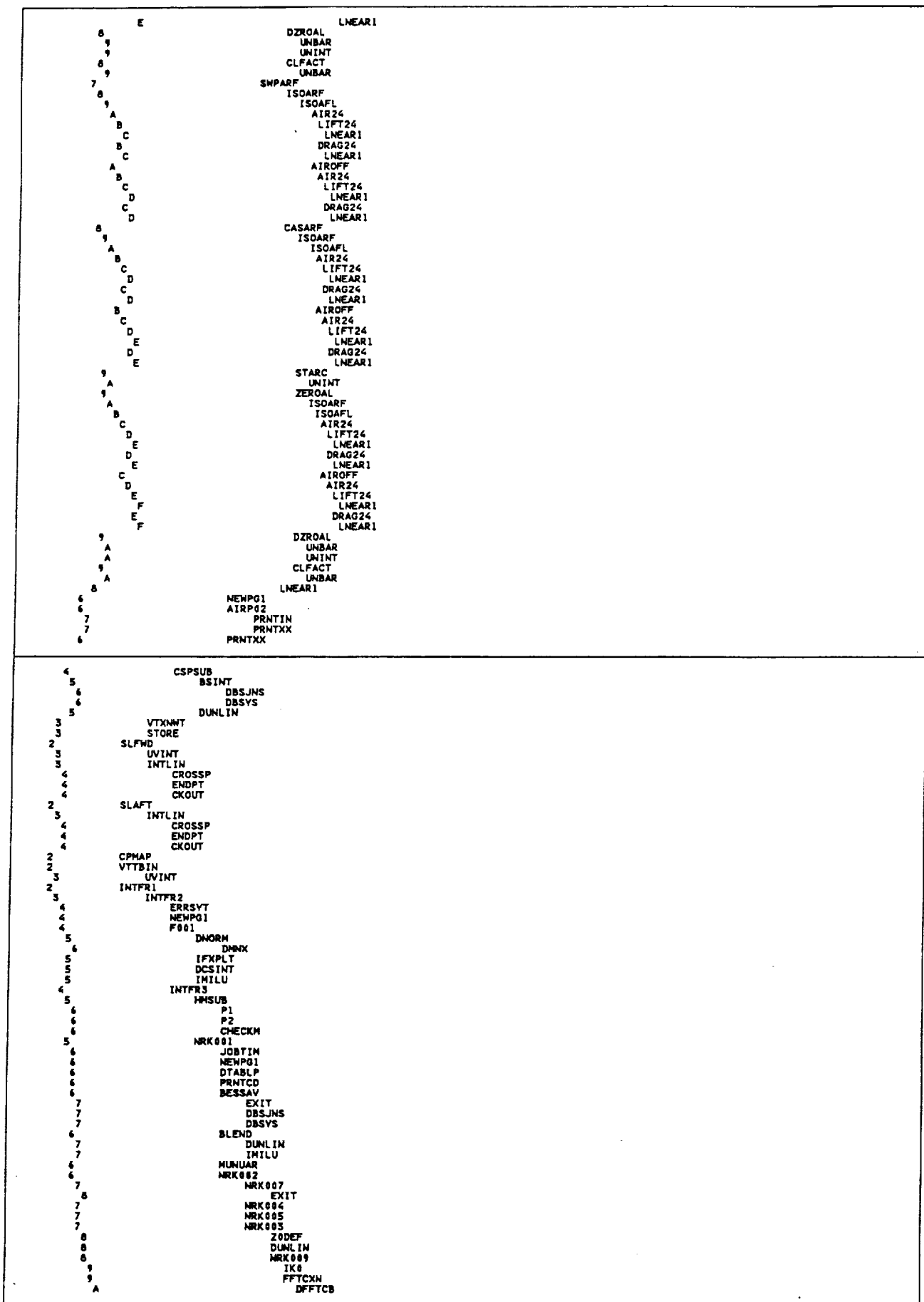


Figure 3A: UCAP Calling Tree (continued)

Figure 3A: UCAP Calling Tree (continued)

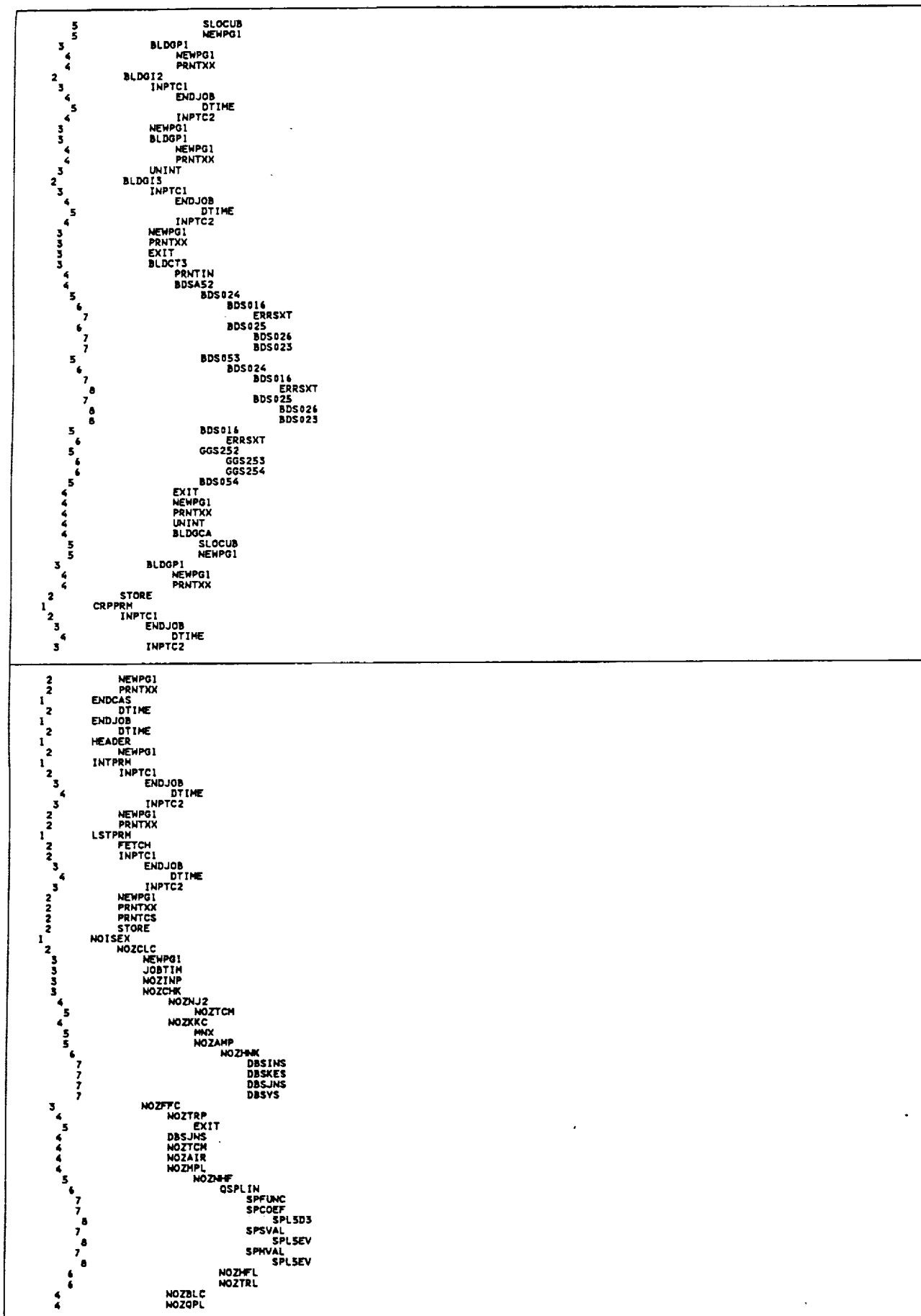


Figure 3A: UCAP Calling Tree (continued)

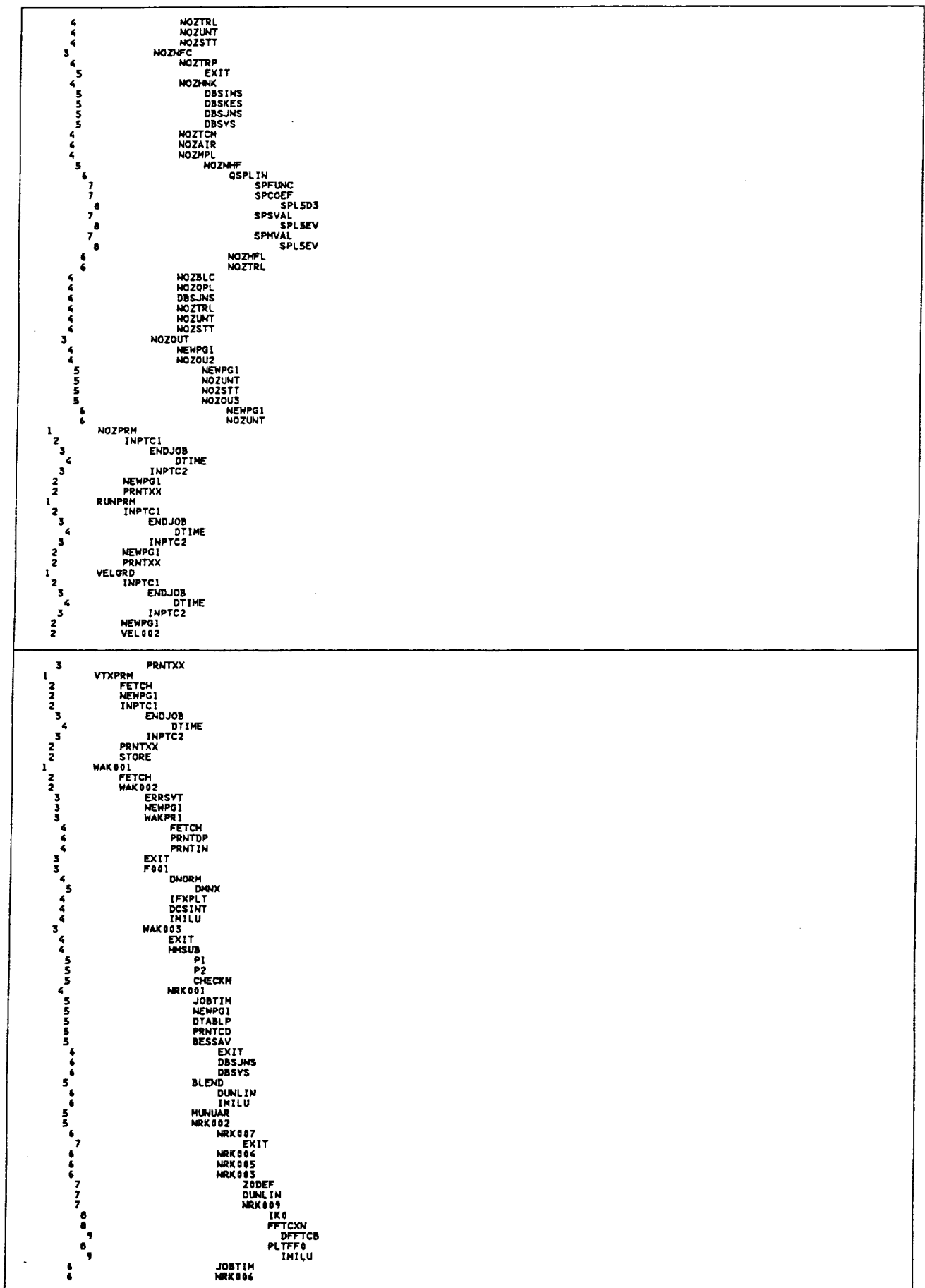
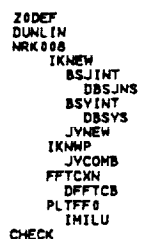


Figure 3A: UCAP Calling Tree (continued)



92

C-2

**** TSO FOREGROUND HARDCOPY **** 10:34:35 93112
DSNAME=TSO0041.XREF1.DATA

SUBROUTINE CROSS REFERENCE LISTING

SUBR. SUBROUTINES NAMED

```

ABSVAL IS CALLED BY :
ADJUST IS CALLED BY : LSTCTL
AIRDR0 IS CALLED BY : AIRPRM ANS0 ANS0M0
AIRFLX IS CALLED BY : AIRDR0
AIROFF IS CALLED BY : ISOAFL
AIRPRM IS CALLED BY : MAIN
AIRP02 IS CALLED BY : AIRDR0
AIR24 IS CALLED BY : AIROFF ISOAFL
ANS IS CALLED BY : F271
ANSN1 IS CALLED BY : ANS
ANS0 IS CALLED BY : F271
ANS0M0 IS CALLED BY : F271M0
ANS0N1 IS CALLED BY : ANS0 ANS0M0
ARCTAN IS CALLED BY :
AIK2 IS CALLED BY : KHATRX KHATR0
BDSAS2 IS CALLED BY : BLDCT3
BDS004 IS CALLED BY : BDS052
BDS010 IS CALLED BY : BDS014
BDS011 IS CALLED BY : BDS014
BDS012 IS CALLED BY : BDS014
BDS013 IS CALLED BY : BDS014 MLINE
BDS014 IS CALLED BY : BDS015
BDS015 IS CALLED BY : BDS004
BDS016 IS CALLED BY : BDSAS2 BDS024 BDS052
BDS018 IS CALLED BY : BDS014
BDS019 IS CALLED BY : BDS014 MLINE
BDS020 IS CALLED BY : BDS011 BDS014
BDS023 IS CALLED BY : BDS025
BDS024 IS CALLED BY : BDSAS2 BDS014 BDS015 BDS052 BDS053 VEL003
BDS025 IS CALLED BY : BDS024
BDS026 IS CALLED BY : BDS025
BDS052 IS CALLED BY : BLDCT1
BDS053 IS CALLED BY : BDSAS2 BDS052
BDS054 IS CALLED BY : BDSAS2 BDS052
BDS086 IS CALLED BY : BDS104
BDS088 IS CALLED BY : BDS086 BDS089
BDS089 IS CALLED BY : BDS086
BDS095 IS CALLED BY : BDS086
BDS096 IS CALLED BY : BDS086
BDS097 IS CALLED BY : BDS095
BDS104 IS CALLED BY : BDS004
BESSAV IS CALLED BY : F271 NRK001
BLDCT1 IS CALLED BY : BLDG11
BLDCT3 IS CALLED BY : BLDG13
BLDGCA IS CALLED BY : BLDCT1 BLDCT3
BLDGEM IS CALLED BY : MAIN
BLDG11 IS CALLED BY : BLDGEM
BLDG12 IS CALLED BY : BLDGEM
BLDG13 IS CALLED BY : BLDGEM
BLDGP1 IS CALLED BY : BLDG11 BLDG12 BLDG13
BLEND IS CALLED BY : F271 F271M0 NRK001
BOUND IS CALLED BY : KHATRX KHATR0

BOUND0 IS CALLED BY : KHATR0
BSINT IS CALLED BY : CSPSUB
BSJINT IS CALLED BY : IKNEW
BSVINT IS CALLED BY : IKNEW
CAMTHA IS CALLED BY : BDS010 BDS014
CASARF IS CALLED BY : AIRFLX SWPARF
CENTER IS CALLED BY : BOUND
CHECK IS CALLED BY : MSUM NRK006 THICK3 WAKE WAKE00 WAKESN WAKES0
CHECKM IS CALLED BY : HMSUB
CKOUT IS CALLED BY : INTLIN
CLFACT IS CALLED BY : CASARF
CONVR0 IS CALLED BY :
CPHAP IS CALLED BY : LSTCTL
CPYSDP IS CALLED BY : LSTCTL
CROSSP IS CALLED BY : INTLIN
CRPPRM IS CALLED BY : MAIN
CSPSUB IS CALLED BY : F271 F271M0
CTRAP IS CALLED BY : RADINT
CUNLIN IS CALLED BY : RADINT
DEF20 IS CALLED BY : BOUND
DMNX IS CALLED BY : DNORM
DNORM IS CALLED BY : F001
DRAG24 IS CALLED BY : AIR24
DSLOCB IS CALLED BY : ANS
DTABLP IS CALLED BY : F271 NRK001
DTRAP IS CALLED BY : INTFRS
DUNBAR IS CALLED BY : ANS ANS0 ANS0M0
DUNLIN IS CALLED BY : ANS ANSN1 ANS0M0 ANS0N1 BLEND BOUND BOUND0 CSPSUB F271 INTFRS
DUNLIN IS CALLED BY : KHATRX KHATR0 LSTVVC NRK003 NRK006 THICK0 THICK3 WAKE WAKE00 WAKESN
DUNLIN IS CALLED BY : WAKES0 WAKM0 WAKM01 WAK004
DZROAL IS CALLED BY : CASARF
ENDCAS IS CALLED BY : MAIN
ENDJOB IS CALLED BY : MAIN INPTC1
ENDPT IS CALLED BY : INTLIN
ERRSXT IS CALLED BY : BDS014
ERRSYT IS CALLED BY : INTFR2 WAK002
ETACAL IS CALLED BY :
FETCH IS CALLED BY : LSTDY LSTPRM LSTUNS MCAFA VTXPRM WAKPRM WAKPR1 WAK001
FEXP IS CALLED BY :
FFTCX IS CALLED BY : INFFNS WINGIN
FFTCXN IS CALLED BY : NRK008 NRK009
FFTCX0 IS CALLED BY : INF INFFN0
FFUN IS CALLED BY :
F001 IS CALLED BY : INTFR2 WAK002
F271 IS CALLED BY : LSTDY LSTUNS
F271M0 IS CALLED BY : LSTDY
GETXMB IS CALLED BY : LSTCTL
GGS011 IS CALLED BY : BDS052
GGS107 IS CALLED BY : BDS052
GGS252 IS CALLED BY : BDSAS2 BDS052
GGS253 IS CALLED BY : GGS252
GGS254 IS CALLED BY : GGS252
HEADER IS CALLED BY : MAIN
HMSUB IS CALLED BY : INTFR3 WAK003
HS1 IS CALLED BY : BDS014
HS2 IS CALLED BY : BDS014
H455S IS CALLED BY : BDS014
IBIN IS CALLED BY :
IFXPLT IS CALLED BY : F001 NRK01A NRK010
IIXPS IS CALLED BY : BOUND0 THICK0 THICK3
IIXEYV IS CALLED BY : BOUND

```

Figure 3B: UCAP Subroutine Cross Reference Listing

```

IKCOMB IS CALLED BY : SUM4 SUM5 WAKE WAKES0
IKHEW IS CALLED BY : IKSUB INF INFFNO NRK000
IKMWP IS CALLED BY : INFFNO NRK000
IKPCMB IS CALLED BY : SUM3 WAKES0
IKSUB IS CALLED BY : INFFNS
IKSUB0 IS CALLED BY : INFFNS
IK0 IS CALLED BY : INFFNO NRK000
IMLU IS CALLED BY : ANSN1 ANS0M1 BLEND F001 NRK01A NRK010 PLTFFT PLTFF0
IMNSIN IS CALLED BY : WAKESN WAKES0 WAKM01
IMNSUB IS CALLED BY : WAKE WAKE00
INF IS CALLED BY : THICK0 THICK3
INFFNS IS CALLED BY : MSUM
INFFNO IS CALLED BY : BOUND00
INPTC1 IS CALLED BY : AIRPRM BLDG11 BLDG12 BLDG13 CRPPRM INTPRM LSTPRM NOZPRM RUNPRM VELGRD
INPTC1 IS CALLED BY : VTXPRM WAKPRM
INPTC2 IS CALLED BY : INPTC1
INPTRW IS CALLED BY : MAIN
INTFRS IS CALLED BY : LSTCTL
INTFR1 IS CALLED BY : LSTCTL
INTFR2 IS CALLED BY : INTFR1
INTFR3 IS CALLED BY : INTFR2
INTLIN IS CALLED BY : SLAFT SLFWD
INTPRM IS CALLED BY : MAIN
IPKCHB IS CALLED BY : SUM3 WAKES0
ISOARF IS CALLED BY : ISOARF
ISOARF IS CALLED BY : AIRFLX CASARF SWPARF ZEROAL
JOBTIM IS CALLED BY : MAIN F271 F271NO KHATRX KHATR0 NOZCLC NRK001 NRK002
JYCOMB IS CALLED BY : IKMWP IKSUB
JYNEW IS CALLED BY : IKNEW
KIMFIL IS CALLED BY : LSTCTL
KHATRX IS CALLED BY : F271
KHATR0 IS CALLED BY : F271
LESWP IS CALLED BY : GETXMB
LIFT24 IS CALLED BY : AIR24
LINEAR1 IS CALLED BY : DRAG24 LIFT24 SWPARF
LSTCGA IS CALLED BY : LSTSW1
LSTCTL IS CALLED BY : MAIN
LSTDY IS CALLED BY : LSTCTL
LSTPRM IS CALLED BY : MAIN
LSTSW1 IS CALLED BY : MCAFA
LSTUNS IS CALLED BY : LSTCTL
LSTVVC IS CALLED BY : ANS0
LSTVZ IS CALLED BY : LSTSW1
MAIN IS CALLED BY :
MCAFA IS CALLED BY : GETXMB
MEAN IS CALLED BY :
MLINE IS CALLED BY : BDS014
MNK IS CALLED BY : NOZKCC
MOMCAL IS CALLED BY : LSTDY
MSUM IS CALLED BY : BOUND
MUNUAR IS CALLED BY : F271 F271NO NRK001
NEWPO1 IS CALLED BY : ADJUST AIRDRG AIRPRM ANSN1 ANS0 ANS0NO BLDCT1 BLDCT3 BLDGCA BLDG11
NEWPO1 IS CALLED BY : BLDG12 BLDG13 BLDG1 CRPPRM F271 HEADER INPTRW INTFR2 INTPRM LSTCTL
NEWPO1 IS CALLED BY : NRK001 NRK01A NRK010 PRTPRF RUNPRM VELGRD VEL003 VTXOUT VTXPRM WAKPRM
NEWPO1 IS CALLED BY : WAK002
NEWPO1 IS CALLED BY : LSTDY LSTPRM LSTUNS LSTVVC MCAFA NOZCLC NOZOUT NOZ0U2 NOZ0U3 NOZPRM
NOISEX IS CALLED BY : MAIN
NOZAIR IS CALLED BY : NOZFFC NOZNFC
NOZAMP IS CALLED BY : NOZKCC
NOZBLC IS CALLED BY : NOZFFC NOZNFC
NOZCHK IS CALLED BY : NOZCLC

```

```

NOZCLC IS CALLED BY : NOISEX
NOZFFC IS CALLED BY : NOZCLC
NOZHFL IS CALLED BY : NOZNMF
NOZHNK IS CALLED BY : NOZAMP NOZNFC
NOZINP IS CALLED BY : NOZCLC
NOZKCC IS CALLED BY : NOZCHK
NOZHPL IS CALLED BY : NOZFFC NOZNFC
NOZNFC IS CALLED BY : NOZCLC
NOZNHF IS CALLED BY : NOZMPL
NOZNJ2 IS CALLED BY : NOZCHK
NOZOUT IS CALLED BY : NOZCLC
NOZ0U2 IS CALLED BY : NOZOUT
NOZ0U3 IS CALLED BY : NOZ0U2
NOZPRM IS CALLED BY : MAIN
NOZQPL IS CALLED BY : NOZFFC NOZNFC
NOZSTT IS CALLED BY : NOZFFC NOZNFC NOZ0U2
NOZTRM IS CALLED BY : NOZFFC NOZNFC NOZNJ2
NOZTRP IS CALLED BY : NOZFFC NOZNFC NOZNHF
NOZUNT IS CALLED BY : NOZFFC NOZNFC NOZ0U2 NOZ0U3
NRK001 IS CALLED BY : INTFR3 WAK003
NRK002 IS CALLED BY : NRK001
NRK003 IS CALLED BY : NRK002
NRK004 IS CALLED BY : NRK002
NRK005 IS CALLED BY : NRK002
NRK006 IS CALLED BY : NRK002
NRK007 IS CALLED BY : NRK002
NRK008 IS CALLED BY : NRK006
NRK009 IS CALLED BY : NRK003
NRK01A IS CALLED BY : INTFR3
NRK01B IS CALLED BY : NRK01A
NRK010 IS CALLED BY : WAK003
NRK011 IS CALLED BY : NRK010
PF1 IS CALLED BY : BDS014
PF2 IS CALLED BY : BDS014
PLTFFT IS CALLED BY : INFFNS WINGIN
PLTFF0 IS CALLED BY : INF INFFNO NRK000 NRK000
PRNTCD IS CALLED BY : F271 NRK001
PRNTCS IS CALLED BY : LSTPRM
PRNTDP IS CALLED BY : F271 LSTVVC VEL003 WAKPR1
PRNTIN IS CALLED BY : AIRP02 BLDCT1 BLDCT3 F271 LSTVVC MCAFA VEL003 WAKPR1
PRNTXX IS CALLED BY : WAKPRM
PRNTXX IS CALLED BY : LSTDY LSTPRM LSTUNS LSTVVC MCAFA NOZPRM RUNPRM VEL002 VEL003 VTXPRM
PRNTXX IS CALLED BY : AIRDRG AIRPRM AIRP02 BLDCT1 BLDCT3 BLDG11 BLDG13 BLDG1 CRPPRM INTPRM
PRTPRF IS CALLED BY : LSTCTL
PSIK2 IS CALLED BY : THICK
P1 IS CALLED BY : HNSUB
P2 IS CALLED BY : HNSUB
QSPLIN IS CALLED BY : BLDCT1 LSTSW1 NOZNMF
RADINT IS CALLED BY : BOUND
RETRV IS CALLED BY :
RJF IS CALLED BY :
RLCODE IS CALLED BY :
RUNPRM IS CALLED BY : MAIN
R4ARAY IS CALLED BY : INFFNS WINGIN
SETIO IS CALLED BY : LSTCTL
SETLMT IS CALLED BY :
SLAFT IS CALLED BY : LSTCTL
SLFWD IS CALLED BY : LSTCTL
SLOCUB IS CALLED BY : BLDGCA
SHWAK IS CALLED BY : BOUND

```

Figure 3B: UCAP Subroutine Cross Reference Listing (continued)


```

SPWAK0 IS CALLED BY : BOUND
SPCOEF IS CALLED BY : QSPLIN
SPECIN IS CALLED BY : IKSUB0
SPFUNC IS CALLED BY : QSPLIN
SPLSD3 IS CALLED BY : SPCOEF
SPLSEV IS CALLED BY : SPMVAL SPSVAL
SPMVAL IS CALLED BY : QSPLIN
SPSVAL IS CALLED BY : QSPLIN
SPZERO IS CALLED BY : LSTCTL
STARC IS CALLED BY : CASARF
STDDEV IS CALLED BY :
STDIKI IS CALLED BY : INTFRS
STORE IS CALLED BY : MAIN BLDGEM LSTDY LSTPRM LSTUNS MCAFA VTXPRM WAKPRM WAK001
SUM1 IS CALLED BY : WAKESN
SUM2 IS CALLED BY : WAKESN
SUM3 IS CALLED BY : WAKESN
SUM4 IS CALLED BY : WAKESN
SUM5 IS CALLED BY : WAKESN
SUM6 IS CALLED BY : WAKESN
SWPARF IS CALLED BY : AIRFLX
THICK IS CALLED BY : F271
THICK0 IS CALLED BY : THICK
THICK3 IS CALLED BY : THICK
THVFIL IS CALLED BY : LSTCTL
TIKSUB IS CALLED BY : INF
TIKA IS CALLED BY : INF
UNBAR IS CALLED BY : CLFACT DZROAL
UNINT IS CALLED BY : BLDCT1 BLDCT3 BLDG12 DZROAL STARC
UNLIN IS CALLED BY : GETXMB
UVINT IS CALLED BY : ADJUST ANS0 ANS0NO BLDCT1 SLFWD VTTBIN
UVISC IS CALLED BY :
VELORD IS CALLED BY : MAIN
VEL002 IS CALLED BY : VELGRD
VEL003 IS CALLED BY : LSTVVC
VTTBIN IS CALLED BY : LSTCTL
VTXAU0 IS CALLED BY : VTXCAL
VTXCAL IS CALLED BY : LSTDY
VTXCDZ IS CALLED BY : VTXCAL
VTXCSE IS CALLED BY : VTXCAL
VTXDB0 IS CALLED BY : VTXCAL
VTXDLE IS CALLED BY : VTXCAL
VTXINI IS CALLED BY : VTXCAL
VTXKST IS CALLED BY : VTXCAL
VTXNMT IS CALLED BY : LSTDY LSTUNS
VTXOUT IS CALLED BY : LSTDY VTXCAL
VTXPRF IS CALLED BY : VTXCAL
VTXPRM IS CALLED BY : MAIN
VTXWRD IS CALLED BY : LSTDY
WAKE IS CALLED BY : KMATRX
WAKEQ0 IS CALLED BY : KMATRX
WAKESN IS CALLED BY : WAKE
WAKES0 IS CALLED BY : WAKEQ0
WAKM0 IS CALLED BY : KMATRX
WAKM01 IS CALLED BY : WAKM0
WAKPRM IS CALLED BY : MAIN
WAKPR1 IS CALLED BY : WAK002
WAK001 IS CALLED BY : MAIN
WAK002 IS CALLED BY : WAK001
WAK003 IS CALLED BY : WAK002
WAK004 IS CALLED BY : INTFR3 WAK003
WING IS CALLED BY : BOUND

```

```

WINGF IS CALLED BY : WINGIN
WINGIN IS CALLED BY : WING
ZEROAL IS CALLED BY : CASARF
ZODEF IS CALLED BY : BOUND0 NRK005 NRK006 THICK0 THICK3

```

Figure 3B: UCAP Subroutine Cross Reference Listing (continued)

```

CALL ($) : EXIT      BDS004 GGS107 GGS011 BDS024 BDS053 BDS016 GGS252 BDS054
SUBROUTINE BDS053    PURPOSE :
CALL ($) : BDS024
SUBROUTINE BDS054    PURPOSE :
SUBROUTINE BDS066    PURPOSE :
CALL ($) : BDS096 BDS095 BDS089 BDS088
SUBROUTINE BDS088    PURPOSE :
SUBROUTINE BDS089    PURPOSE :
CALL ($) : BDS088
SUBROUTINE BDS095    PURPOSE :
CALL ($) : BDS097
SUBROUTINE BDS096    PURPOSE :
SUBROUTINE BDS097    PURPOSE :
SUBROUTINE BDS104    PURPOSE :
CALL ($) : BDS086
SUBROUTINE BESSAV    PURPOSE :
CALL ($) : EXIT      DBSJNS DBSYS
SUBROUTINE BLDCT1    PURPOSE :
CALL ($) : QSPLIN UVINT NEWPG1 PRNTIN PRNTXX BDS052 EXIT  UNINT  BLDGCA
SUBROUTINE BLDCT3    PURPOSE :
CALL ($) : PRNTIN BDSA52 EXIT  NEWPG1 PRNTXX UNINT  BLDGCA
SUBROUTINE BLDGCA    PURPOSE :
CALL ($) : SLOCUB NEWPG1
SUBROUTINE BLDGEM    PURPOSE :
CALL ($) : BLDG11 BLDG12 BLDG13 STORE
SUBROUTINE BLDG11    PURPOSE :
CALL ($) : INPTC1 NEWPG1 PRNTXX BLDCT1 BLDGP1
SUBROUTINE BLDG12    PURPOSE :
CALL ($) : INPTC1 NEWPG1 BLDGP1 UNINT
SUBROUTINE BLDG13    PURPOSE :
CALL ($) : INPTC1 NEWPG1 PRNTXX EXIT  BLDCT3 BLDGP1
SUBROUTINE BLDGP1    PURPOSE :
CALL ($) : NEWPG1 PRNTXX
SUBROUTINE BLEND     PURPOSE :
CALL ($) : DUNLIN IMILU
SUBROUTINE BOUND     PURPOSE :
CALL ($) : SHMAX0 SHMAX DUNLIN IIXXY DEFZ0 MSUM  WING  CENTER RADINT
SUBROUTINE BOUND0    PURPOSE :
CALL ($) : DUNLIN IIXXP5 Z0DEF  INFFN0
SUBROUTINE BSINT     PURPOSE :
CALL ($) : DBSJNS DBSYS
SUBROUTINE BSJINT    PURPOSE :
CALL ($) : DBSJNS
SUBROUTINE BSJINT    PURPOSE :
CALL ($) : DBSYS
SUBROUTINE CANTHA    PURPOSE :
CALL ($) : EXIT
SUBROUTINE CASARF    PURPOSE :
CALL ($) : ISOARF STARC  ZEROAL DZROAL CLFACT
SUBROUTINE CENTER    PURPOSE :
SUBROUTINE CHECK     PURPOSE :
SUBROUTINE CHECKM    PURPOSE :
SUBROUTINE CKOUT     PURPOSE :
SUBROUTINE CLFACT    PURPOSE :
CALL ($) : UNBAR
SUBROUTINE CONVRG    PURPOSE :
SUBROUTINE CPHAP     PURPOSE :
SUBROUTINE CPVSP     PURPOSE :
SUBROUTINE CROSSP    PURPOSE :
SUBROUTINE CRPPRH    PURPOSE :
CALL ($) : INPTC1 NEWPG1 PRNTXX

```

SUBROUTINE CSPSUB	PURPOSE :	BSINT DUNLIN
SUBROUTINE CTRAP	CALL (S) :	
SUBROUTINE CUNLIN	PURPOSE :	
SUBROUTINE DEFZ0	PURPOSE :	
SUBROUTINE DMNX	PURPOSE :	
SUBROUTINE DNORM	PURPOSE :	
	CALL (S) :	DMNX
SUBROUTINE DRAG24	PURPOSE :	
	CALL (S) :	LNEARI
SUBROUTINE DSLOCB	PURPOSE :	
SUBROUTINE DTABLP	PURPOSE :	
SUBROUTINE DTRAP	PURPOSE :	
SUBROUTINE DUNBAR	PURPOSE :	
SUBROUTINE DUNLIN	PURPOSE :	
SUBROUTINE DZROAL	PURPOSE :	
	CALL (S) :	UNBAR UNINT
SUBROUTINE ENDCAS	PURPOSE :	
	CALL (S) :	DTIME
SUBROUTINE ENDJOB	PURPOSE :	
	CALL (S) :	DTIME
SUBROUTINE ENDPT	PURPOSE :	
SUBROUTINE ERRSXT	PURPOSE :	
SUBROUTINE ERRSYT	PURPOSE :	
SUBROUTINE ETACAL	PURPOSE :	
SUBROUTINE FETCH	PURPOSE :	
SUBROUTINE FEXP	PURPOSE :	
SUBROUTINE FFTCX	PURPOSE :	
	CALL (S) :	DFFTCB
SUBROUTINE FFTCXN	PURPOSE :	
	CALL (S) :	DFFTCB
SUBROUTINE FFTCX0	PURPOSE :	
	CALL (S) :	DFFTCB
SUBROUTINE FFUN	PURPOSE :	
SUBROUTINE F001	PURPOSE :	
	CALL (S) :	DNORM IFXPLT DCSINT IMILU
SUBROUTINE F271	PURPOSE :	
	CALL (S) :	JOBTIM NEWPG1 PRNTDP PRNTIN DTABLP PRNTCD EXIT DUNLIN BESSAV BLEND
	CALL (S) :	MUNUAR KMATRX KMATR0 THICK ANS ANS0 CSPSUB
SUBROUTINE F271NO	PURPOSE :	
	CALL (S) :	JOBTIM EXIT BLEND MUNUAR DLINRG ANS0NO CSPSUB
SUBROUTINE GETXMB	PURPOSE :	
	CALL (S) :	HCAFA UNLIN LESWP
SUBROUTINE GGS011	PURPOSE :	
SUBROUTINE GGS107	PURPOSE :	
SUBROUTINE GGS252	PURPOSE :	
	CALL (S) :	GGS253 GGS254
SUBROUTINE GGS253	PURPOSE :	
SUBROUTINE GGS254	PURPOSE :	
SUBROUTINE HEADER	PURPOSE :	
	CALL (S) :	NEWPG1
SUBROUTINE HHSUB	PURPOSE :	
	CALL (S) :	P1 P2 CHECKN
SUBROUTINE HS1	PURPOSE :	
	CALL (S) :	EXIT
SUBROUTINE HS2	PURPOSE :	
	CALL (S) :	EXIT
SUBROUTINE H455S	PURPOSE :	
	CALL (S) :	EXIT
SUBROUTINE IBIN	PURPOSE :	
SUBROUTINE IFXPLT	PURPOSE :	
SUBROUTINE IIEXPS	PURPOSE :	
	CALL (S) :	EXIT
SUBROUTINE IIEXYV	PURPOSE :	
	CALL (S) :	EXIT
SUBROUTINE IKCOMB	PURPOSE :	
SUBROUTINE IKNEW	PURPOSE :	
	CALL (S) :	BSJINT BSVINT JYNEW
SUBROUTINE IKNWP	PURPOSE :	
	CALL (S) :	JYCOMB
SUBROUTINE IKPCMB	PURPOSE :	
SUBROUTINE IKSUB	PURPOSE :	
	CALL (S) :	IKNEW JYCOMB
SUBROUTINE IKSUB0	PURPOSE :	
	CALL (S) :	SPECIN
SUBROUTINE IK0	PURPOSE :	
SUBROUTINE IMILU	PURPOSE :	
SUBROUTINE IMNSIN	PURPOSE :	
SUBROUTINE IMNSUB	PURPOSE :	
SUBROUTINE INF	PURPOSE :	
	CALL (S) :	IKNEW TIKSUB TIK0 FFTCX0 PLTFF0
SUBROUTINE INFFNS	PURPOSE :	
	CALL (S) :	IKSUB IKSUB0 FFTCX R4ARAY PLTFFY
SUBROUTINE INFFN0	PURPOSE :	
	CALL (S) :	IKNEW IKNWP IK0 FFTCX0 PLTFF0
SUBROUTINE INPTC1	PURPOSE :	
	CALL (S) :	ENDJOB INPTC2
SUBROUTINE INPTC2	PURPOSE :	
SUBROUTINE INPTRN	PURPOSE :	
	CALL (S) :	NEWPG1
SUBROUTINE INTFRS	PURPOSE :	
	CALL (S) :	DUNLIN STDIKI DTRAP
SUBROUTINE INTFR1	PURPOSE :	
	CALL (S) :	INTFR2
SUBROUTINE INTFR2	PURPOSE :	
	CALL (S) :	ERRSVT NEWPG1 F001 INTFR3
SUBROUTINE INTFR3	PURPOSE :	
	CALL (S) :	HHSUB MRK001 WAK004 MRK01A
SUBROUTINE INTLIN	PURPOSE :	
	CALL (S) :	CROSSP ENDPT CKOUT
SUBROUTINE INTPRM	PURPOSE :	
	CALL (S) :	INPTC1 NEWPG1 PRNTXX
SUBROUTINE IPKCMH	PURPOSE :	
SUBROUTINE ISOAFL	PURPOSE :	
	CALL (S) :	AIR24 AIROFF
SUBROUTINE ISOARF	PURPOSE :	
	CALL (S) :	ISOAFL
SUBROUTINE JOBTIM	PURPOSE :	
SUBROUTINE JYCOMB	PURPOSE :	
SUBROUTINE JYNEW	PURPOSE :	
SUBROUTINE KINFIL	PURPOSE :	
SUBROUTINE KMATRX	PURPOSE :	
	CALL (S) :	DUNLIN AIK2 JOBTIM WAKE BOUND DLINCG
SUBROUTINE KMATR0	PURPOSE :	
	CALL (S) :	AIK2 DUNLIN WAKH0 BOUND0 JOBTIM WAKE0 BOUND DLINR0
SUBROUTINE LESWP	PURPOSE :	
SUBROUTINE LIFT24	PURPOSE :	
	CALL (S) :	LNEARI
SUBROUTINE LNEARI	PURPOSE :	
SUBROUTINE LSTCGA	PURPOSE :	
SUBROUTINE LSTCYL	PURPOSE :	
	CALL (S) :	CPHAP VTTBIN INTFR1 CPYSDP INTFRS PRTPRF ADJUST

Figure 3C: UCAP Subroutine Reference and Purpose Listing (cont)

SUBROUTINE LSTDV	CALL (S) : SPZERO SETIO GETXMB KINFIL THVFIL LSTDV NEWPG1 LSTUNS SLFWD SLAFT
	PURPOSE :
	CALL (S) : STORE
SUBROUTINE LSTPRM	CALL (S) : FETCH NEWPG1 PRNTXX F271NO F271 VTXCAL VTXOUT VTXWMT VTXWRD MOMCAL
	PURPOSE :
SUBROUTINE LSTSWI	CALL (S) : FETCH INPTC1 NEWPG1 PRNTXX PRNTCS STORE
	PURPOSE :
SUBROUTINE LSTUNS	CALL (S) : QSPLIN LSTCGA LSTXYZ
	PURPOSE :
SUBROUTINE LSTVVC	CALL (S) : FETCH NEWPG1 PRNTXX F271 VTXWMT STORE
	PURPOSE :
SUBROUTINE LSTXYZ	CALL (S) : NEWPG1 PRNTDP PRNTIN DUNLIN VEL003 PRNTXX
SUBROUTINE MAIN	PURPOSE :
	CALL (S) : ENDCAS ENDJOB HEADER INTPRM LSTPRM NOISEX NOZPRM RUNPRM VELGRD VTXPRM
	CALL (S) : WAK001 WAKPRM
	CALL (S) : IMKIN JOBTIM DTIME TDATE INPTRM STORE LSTCTL AIRPRM BLDGEM CRPPRM
	PURPOSE :
SUBROUTINE HCAFA	CALL (S) : FETCH NEWPG1 TOLSTS PRNTXX PRNTIN LSTSWI STORE
	PURPOSE :
SUBROUTINE MEAN	PURPOSE :
SUBROUTINE MLINE	PURPOSE :
	CALL (S) : BDS019 BDS013
	PURPOSE :
SUBROUTINE MNX	PURPOSE :
SUBROUTINE MOMCAL	PURPOSE :
SUBROUTINE MSUM	PURPOSE :
	CALL (S) : INFFNS CHECK
	PURPOSE :
SUBROUTINE MUNUAR	PURPOSE :
SUBROUTINE NEWPG1	PURPOSE :
SUBROUTINE NOISEX	PURPOSE :
	CALL (S) : NOZCLC
	PURPOSE :
SUBROUTINE NOZAIR	PURPOSE :
SUBROUTINE NOZAMP	PURPOSE :
	CALL (S) : NOZHNK
	PURPOSE :
SUBROUTINE NOZBLC	PURPOSE :
SUBROUTINE NOZCHK	PURPOSE :
	CALL (S) : NOZNJ2 NOZKKC
	PURPOSE :
SUBROUTINE NOZCLC	CALL (S) : NEWPG1 JOBTIM NOZINP NOZCHK NOZFFC NOZNFC NOZOUT
	PURPOSE :
SUBROUTINE NOZFFC	CALL (S) : NOZTRP DBSJNS NOZTCM NOZAIR NOZMPL NOZBLC NOZQPL NOZTRL NOZUNT NOZSTT
	PURPOSE :
SUBROUTINE NOZHFL	PURPOSE :
SUBROUTINE NOZHNK	PURPOSE :
	CALL (S) : DBSJNS DBSKES DBSJNS DBSYS
	PURPOSE :
SUBROUTINE NOZINP	PURPOSE :
SUBROUTINE NOZKKC	CALL (S) : MNX NOZAMP
	PURPOSE :
SUBROUTINE NOZMPL	CALL (S) : NOZNHF
	PURPOSE :
SUBROUTINE NOZNFC	PURPOSE :
	CALL (S) : NOZSTT
	CALL (S) : NOZTRP NOZHNK NOZTCM NOZAIR NOZMPL NOZBLC NOZQPL DBSJNS NOZTRL NOZUNT
	PURPOSE :
SUBROUTINE NOZHNH	CALL (S) : QSPLIN NOZHFL NOZTRL
	PURPOSE :
SUBROUTINE NOZNJ2	CALL (S) : NOZTCM
	PURPOSE :
SUBROUTINE NOZOUT	CALL (S) : NEWPG1 NOZOU2
	PURPOSE :
SUBROUTINE NOZOU2	CALL (S) : NEWPG1 NOZUNT NOZSTT NOZOU3
	PURPOSE :
SUBROUTINE NOZOU3	CALL (S) : NEWPG1 NOZUNT

SUBROUTINE NOZPRM	PURPOSE :
	CALL (S) : INPTC1 NEWPG1 PRNTXX
	PURPOSE :
SUBROUTINE NOZQPL	PURPOSE :
SUBROUTINE NOZSTT	PURPOSE :
SUBROUTINE NOZTCM	PURPOSE :
SUBROUTINE NOZTRL	PURPOSE :
SUBROUTINE NOZTRP	PURPOSE :
	CALL (S) : EXIT
SUBROUTINE NOZUNT	PURPOSE :
SUBROUTINE NRK001	PURPOSE :
	CALL (S) : JOBTIM NEWPG1 DTABLP PRNTCD BESSAV BLEND MUNUAR NRK002
	PURPOSE :
SUBROUTINE NRK002	CALL (S) : NRK007 NRK004 NRK005 NRK003 JOBTIM NRK006
	PURPOSE :
SUBROUTINE NRK003	CALL (S) : Z0DEF DUNLIN NRK009
	PURPOSE :
SUBROUTINE NRK004	PURPOSE :
SUBROUTINE NRK005	PURPOSE :
SUBROUTINE NRK006	PURPOSE :
	CALL (S) : Z0DEF DUNLIN NRK008 CHECK
	PURPOSE :
SUBROUTINE NRK007	PURPOSE :
	CALL (S) : EXIT
SUBROUTINE NRK008	PURPOSE :
	CALL (S) : IKNEW IKAMP FFTCKN PLTFF0
	PURPOSE :
SUBROUTINE NRK009	CALL (S) : IK0 FFTCKN PLTFF0
	PURPOSE :
SUBROUTINE NRK01A	CALL (S) : NRK01B NEWPG1 IMILU IFXPLT
	PURPOSE :
SUBROUTINE NRK01B	PURPOSE :
SUBROUTINE NRK01C	PURPOSE :
	CALL (S) : EXIT NRK011 NEWPG1 IMILU IFXPLT
	PURPOSE :
SUBROUTINE NRK011	PURPOSE :
SUBROUTINE PF1	PURPOSE :
	CALL (S) : EXIT
SUBROUTINE PF2	PURPOSE :
	CALL (S) : EXIT
SUBROUTINE PLTFFT	PURPOSE :
	CALL (S) : IMILU
SUBROUTINE PLTFF0	PURPOSE :
	CALL (S) : IMILU
	PURPOSE :
SUBROUTINE PRNTCD	PURPOSE :
SUBROUTINE PRNTCS	PURPOSE :
SUBROUTINE PRNTDP	PURPOSE :
SUBROUTINE PRNTIN	PURPOSE :
SUBROUTINE PRNTXX	PURPOSE :
SUBROUTINE PRTPRF	PURPOSE :
	CALL (S) : NEWPG1
	PURPOSE :
SUBROUTINE PSIK2	PURPOSE :
SUBROUTINE P1	PURPOSE :
SUBROUTINE P2	PURPOSE :
SUBROUTINE QSPLIN	PURPOSE :
	CALL (S) : SPFUNC SPCDEF SPSVAL SPNVAL
	PURPOSE :
SUBROUTINE RADINT	CALL (S) : EXIT CUNLIN CTRAP
	PURPOSE :
SUBROUTINE RETREV	PURPOSE :
SUBROUTINE RJF	PURPOSE :
SUBROUTINE RLCODE	PURPOSE :
SUBROUTINE RUNPRM	PURPOSE :
	CALL (S) : INPTC1 NEWPG1 PRNTXX
	PURPOSE :
SUBROUTINE R4ARAY	PURPOSE :
SUBROUTINE SETIO	PURPOSE :
SUBROUTINE SETLMT	PURPOSE :

Figure 3C: UCAP Subroutine Reference and Purpose Listing (cont)

SUBROUTINE SLAFT	PURPOSE :
	CALL (S) : INTLIN
SUBROUTINE SLFWD	PURPOSE :
	CALL (S) : UVINT INTLIN
SUBROUTINE SLOCUB	PURPOSE :
SUBROUTINE SMMAK	PURPOSE :
SUBROUTINE SMMAK0	PURPOSE :
SUBROUTINE SPCOE	PURPOSE :
	CALL (S) : SPL5D3
SUBROUTINE SPECIN	PURPOSE :
SUBROUTINE SPFUNC	PURPOSE :
SUBROUTINE SPL5D3	PURPOSE :
SUBROUTINE SPL5EV	PURPOSE :
SUBROUTINE SPMVAL	PURPOSE :
	CALL (S) : SPL5EV
SUBROUTINE SPSVAL	PURPOSE :
	CALL (S) : SPL5EV
SUBROUTINE SPZERO	PURPOSE :
SUBROUTINE STARC	PURPOSE :
	CALL (S) : UNINT
SUBROUTINE STDDEV	PURPOSE :
SUBROUTINE STDIKI	PURPOSE :
SUBROUTINE STORE	PURPOSE :
SUBROUTINE SUM1	PURPOSE :
SUBROUTINE SUM2	PURPOSE :
SUBROUTINE SUM3	PURPOSE :
	CALL (S) : IKPCMB IKPCMB
SUBROUTINE SUM4	PURPOSE :
	CALL (S) : IKCOMB
SUBROUTINE SUM5	PURPOSE :
	CALL (S) : IKCOMB
SUBROUTINE SUM6	PURPOSE :
SUBROUTINE SWPARF	PURPOSE :
	CALL (S) : ISOARF CASARF LNEARI
SUBROUTINE THICK	PURPOSE :
	CALL (S) : PSIK2 THICK0 THICK3
SUBROUTINE THICK0	PURPOSE :
	CALL (S) : DUNLIN IIEXP5 Z0DEF INF
SUBROUTINE THICK3	PURPOSE :
	CALL (S) : DUNLIN IIEXP5 Z0DEF INF CHECK
SUBROUTINE THVFIL	PURPOSE :
SUBROUTINE TIKSUB	PURPOSE :
SUBROUTINE TIK0	PURPOSE :
SUBROUTINE UNBAR	PURPOSE :
SUBROUTINE UNINT	PURPOSE :
SUBROUTINE UNLIN	PURPOSE :
SUBROUTINE UVINT	PURPOSE :
SUBROUTINE UVISC	PURPOSE :
SUBROUTINE VELGRD	PURPOSE :
	CALL (S) : INPTC1 NEWPG1 VEL002
SUBROUTINE VEL002	PURPOSE :
	CALL (S) : PRNTXX
SUBROUTINE VEL003	PURPOSE :
	CALL (S) : EXIT NEWPG1 PRNTDP PRNTXX PRNTIN BDS024
SUBROUTINE VTTBIN	PURPOSE :
	CALL (S) : UVINT
SUBROUTINE VTXA00	PURPOSE :
SUBROUTINE VTXCAL	PURPOSE :
	CALL (S) : VTXINI VTXKST VTXDLE VTXCSE VTXCDZ VTXA00 VTXPRF VTXDBO VTXOUT
SUBROUTINE VTXCDZ	PURPOSE :
SUBROUTINE VTXCSE	PURPOSE :

SUBROUTINE VTXDBO	PURPOSE :
SUBROUTINE VTXDLE	PURPOSE :
SUBROUTINE VTXINI	PURPOSE :
SUBROUTINE VTXKST	PURPOSE :
SUBROUTINE VTXHMT	PURPOSE :
SUBROUTINE VTXOUT	PURPOSE :
	CALL (S) : NEWPG1
SUBROUTINE VTXPRF	PURPOSE :
SUBROUTINE VTXPRM	PURPOSE :
	CALL (S) : FETCH NEWPG1 INPTC1 PRNTXX STORE
SUBROUTINE VTXWRD	PURPOSE :
SUBROUTINE WAKE	PURPOSE :
	CALL (S) : EXIT DUNLIN DBSINS DBSKES IKCOMB CHECK IMNSUB WAKESN
SUBROUTINE WAKEQ0	PURPOSE :
	CALL (S) : EXIT DUNLIN DBSINS DBSKES CHECK IMNSUB WAKES0
SUBROUTINE WAKESN	PURPOSE :
	CALL (S) : DUNLIN SUM1 CHECK SUM2 SUM3 SUM4 SUM5 SUM6 IMNSIN
SUBROUTINE WAKES0	PURPOSE :
	CALL (S) : DUNLIN IKPCMB IKPCMB CHECK IKCOMB IMNSIN
SUBROUTINE WAKM0	PURPOSE :
	CALL (S) : DUNLIN WAKM01
SUBROUTINE WAKM01	PURPOSE :
	CALL (S) : DUNLIN IMNSIN
SUBROUTINE WAKPRM	PURPOSE :
	CALL (S) : FETCH INPTC1 NEWPG1 PRNTXX STORE
SUBROUTINE WAKPRI	PURPOSE :
	CALL (S) : FETCH PRNTDP PRNTIN
SUBROUTINE WAK001	PURPOSE :
	CALL (S) : FETCH WAK002 STORE
SUBROUTINE WAK002	PURPOSE :
	CALL (S) : ERRSVT NEWPG1 WAKPRI EXIT F001 WAK003
SUBROUTINE WAK003	PURPOSE :
	CALL (S) : EXIT HMSUB NRK001 WAK004 NRK010
SUBROUTINE WAK004	PURPOSE :
	CALL (S) : DUNLIN
SUBROUTINE WING	PURPOSE :
	CALL (S) : WINGIN
SUBROUTINE WINGF	PURPOSE :
	CALL (S) : DBSYS
SUBROUTINE WINGIN	PURPOSE :
	CALL (S) : WINGF FFTCX R4ARAY PLTFFT
SUBROUTINE ZEROAL	PURPOSE :
	CALL (S) : ISOARF
SUBROUTINE Z0DEF	PURPOSE :

Figure 3C: UCAP Subroutine Reference and Purpose Listing (cont)

**** TSO FOREGROUND HARDCOPY **** 10:34:35 93112
DSNAME=TSOG041.XREF3.DATA

LABELLED COMMON AREA CROSS REFERENCE LISTING
LABEL SUBROUTINE

```

IS USED BY : MAIN
AIRALZ IS USED BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24 CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRALZ IS USED BY : SHPARF ZEROAL
AIRCDF IS USED BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24 CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRCDF IS USED BY : SHPARF ZEROAL
AIRCDM IS USED BY : SHPARF ZEROAL
AIRCDM IS USED BY : SHPARF ZEROAL
AIRDAT IS USED BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24 CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRDAT IS USED BY : SHPARF ZEROAL
AIRP01 IS USED BY : AIRDRG AIRFLX AIROFF AIRP02 AIR24 CASARF DRAG24 ISOAFL ISOARF LIFT24
AIRP01 IS USED BY : AIRDRG AIRPRM LSTDY LSTUNS
BDSC01 IS USED BY : BDS016
BDSC02 IS USED BY : BDS016
BDSC03 IS USED BY : BDS014
BESAR IS USED BY : BESSAV BSINT BSJINT BSVINT
BESDEL IS USED BY : BESSAV BSINT BSJINT BSVINT
BLDG03 IS USED BY : FETCH STORE
BLDG03 IS USED BY : BLDCT1 BLDG13 BLDG12 BLDG13 BLDG01 FETCH RETREV STORE LSTDY
BLDG03 IS USED BY : LSTUNS MCAFA
BLDG03 IS USED BY : FETCH RETREV STORE
BLDG03 IS USED BY : BLDCT1 BLDG11 FETCH RETREV STORE MCAFA
BLDG03 IS USED BY : FETCH RETREV STORE
BLDG03 IS USED BY : BLDCT3 BLDG13 FETCH STORE
COM002 IS USED BY : GGS011 GGS107
CRPP01 IS USED BY : CRPPRM RETREV LSTCTL LSTDY LSTUNS LSTVVC NEWP01 NRK001 WAK001
DTETME IS USED BY : AIRPRM BLDGEM BLDG11 BLDG12 BLDG13 BLDG01 HEADER INTPRM INTFR1 INTPRM
DTETME IS USED BY : WAK001
DTETME IS USED BY : LSTCTL LSTDY LSTPRM LSTUNS NEWP01 NOISEX RUNPRM VTXPRM WAKPRM WAKPR1
HEADR1 IS USED BY : HEADER LSTCTL LSTDY LSTUNS NEWP01
HEADR2 IS USED BY : HEADER LSTCTL LSTDY LSTUNS NEWP01
HSQSPL IS USED BY : LSTSW1 NOZMFC OSPLIN
INTP01 IS USED BY : INTFRS INTFR1 INTPRM LSTCTL LSTDY LSTUNS
KCLSAV IS USED BY : ISOARF
LSTP01 IS USED BY : FETCH RETREV STORE LSTDY LSTPRM LSTUNS
LSTP02 IS USED BY : FETCH RETREV STORE
LSTR01 IS USED BY : FETCH STORE
LSTR01 IS USED BY : AIRDRG FETCH STORE INTFR1 LSTDY LSTUNS LSTVVC WAK001
LSTR02 IS USED BY : FETCH STORE INTFR1 LSTDY LSTUNS WAK001
LSTSPR IS USED BY : FETCH STORE
NOZDAT IS USED BY : NOZCLC NOZPRM
NOZS14 IS USED BY : NOZFFC NOZMFC
OUTPUT IS USED BY : BDS014
PROVRS IS USED BY : LSTDY LSTUNS NEWP01
RNCPR1 IS USED BY : LSTCTL LSTDY LSTUNS MCAFA RUNPRM
VTXCOM IS USED BY : FETCH RETREV STORE LSTDY VTXCAL VTXOUT VTXPRM
VTXC02 IS USED BY : FETCH RETREV STORE
VVIIC1 IS USED BY : LSTCTL LSTDY LSTUNS VELGRD VEL002 VTTBIN
WAKP01 IS USED BY : FETCH RETREV STORE LSTDY LSTUNS WAKPRM WAK001
WAKP02 IS USED BY : FETCH RETREV STORE
WAKR01 IS USED BY : FETCH STORE INTFR1 LSTDY LSTUNS WAKPR1 WAK001
WAKSP2 IS USED BY : FETCH STORE
WORK IS USED BY : F271 F271NO INTFR3 LSTCTL LSTDY LSTUNS NRK001 WAK003
WORK1 IS USED BY : F271 F271NO LSTDY LSTUNS
XINDEX IS USED BY : BDS014

```

**** TSO FOREGROUND HARDCOPY **** 10:34:35 93112
DSNAME=TSOG041.XREF4.DATA

LABEL COMMON AREA REFERENCE LISTING
SUBROUTINE

USES : LABELED COMMON

```

R AIRDRG USES : LSTR01 AIRP01 AIRDAT AIRCDF AIRCDM AIRALZ
R AIRFLX USES : AIRDAT AIRCDF AIRCDM AIRALZ
R AIROFF USES : AIRDAT AIRCDF AIRCDM AIRALZ
R AIRPRM USES : AIRP01 DTETME
R AIR24 USES : AIRDAT AIRCDF AIRCDM AIRALZ
R BDS014 USES : BDSC03 XINDEX OUTPUT
R BDS016 USES : BDSC01 BDSC02
R BESSAV USES : BESAR BESDEL
R BLDCT1 USES : BLDG01 BLDGEO
R BLDCT3 USES : BLDG03 BLDGEO
R BLDGEM USES : DTETME
R BLDG11 USES : DTETME BLDG01 BLDGEO
R BLDG12 USES : DTETME BLDGEO
R BLDG13 USES : DTETME BLDG03 BLDGEO
R BLDG01 USES : DTETME BLDGEO
R BSINT USES : BESAR BESDEL
R BSJINT USES : BESAR BESDEL
R BSVINT USES : BESAR BESDEL
R CASARF USES : AIRDAT AIRCDF AIRCDM AIRALZ
R CRPPRM USES : CRPP01
R DRAG24 USES : AIRDAT AIRCDF AIRCDM AIRALZ
R FETCH USES : BLDG03 BLDG03 LSTR01 LSTSPR LSTR02 LSTRS2 WAKR01 WAKSP2
R FETCH USES : WAKP01 WAKP02 LSTP01 LSTP02 VTXCOM VTXC02 BLDG01 BLDG02 BLDGEO BLDGEO
R F271 USES : WORK WORK1
R F271NO USES : WORK WORK1
R GGS011 USES : COM002
R GGS107 USES : COM002
R HEADER USES : DTETME HEADR1 HEADR2
R INTPRM USES : DTETME
R INTFRS USES : INTP01
R INTFR1 USES : LSTR02 LSTR01 INTP01 WAKR01 DTETME
R INTFR3 USES : WORK
R INTPRM USES : DTETME INTP01
R ISOAFL USES : AIRDAT AIRCDF AIRCDM AIRALZ
R ISOARF USES : AIRDAT AIRCDF AIRCDM AIRALZ
R LIFT24 USES : AIRDAT AIRCDF AIRCDM AIRALZ
R LSTCTL USES : WORK HEADR1 HEADR2 DTETME RNCPR1 CRPP01 INTP01 VVIIC1
R LSTDY USES : INTP01 CRPP01 PROVRS HEADR1 HEADR2 DTETME WAKP01 WAKR01 BLDGEO VVIIC1
R LSTDY USES : LSTP01 LSTR02 RNCPR1 AIRP01 LSTR01 WORK WORK1 VTXCOM
R LSTPRM USES : DTETME LSTP01
R LSTSW1 USES : HSQSPL
R LSTUNS USES : INTP01 CRPP01 PROVRS HEADR1 HEADR2 DTETME WAKP01 WAKR01 BLDGEO VVIIC1
R LSTVVC USES : LSTP01 LSTR02 RNCPR1 AIRP01 LSTR01 WORK WORK1
R MAIN USES : LSTR01 CRPP01
R MCAFA USES : BLDG01 BLDGEO RNCPR1
R NEWP01 USES : PROVRS DTETME HEADR1 HEADR2 CRPP01
R NOISEX USES : DTETME
R NOZCLC USES : NOZDAT
R NOZFFC USES : NOZS14
R NOZMFC USES : NOZS14
R NOZMFC USES : HSQSPL

```

Figure 3D: UCAP Labeled Common Area Reference Listing

R	NOZPRM	USES	: NOZDAT
R	NRK001	USES	: CRPP01 WORK
R	QSPLIN	USES	: HSGSPL
R	RETRV	USES	: CRPP01 WAKP01 WAKP02 LSTP01 LSTP02 VTXCOM VTXC02 BLDG01 BLDG02 BLDGEO
R	RETRV	USES	: BLDGKO
R	RUNPRM	USES	: DTETHE RNCPO1
R	STORE	USES	: WAKP01 WAKP02 LSTP01 LSTP02 VTXCOM VTXC02 BLDG01 BLDG02 BLDGEO BLDGKO
R	SWPARF	USES	: BLDG03 BLDG03 LSTR01 LSTR02 LSTR02 LSTRS2 WAKR01 WAKSP2
R	VELGRD	USES	: AIRDAT AIRCDF AIRCDM AIRALZ
R	VEL002	USES	: VIIIC1
R	VTTBIN	USES	: VIIIC1
R	VTXCAL	USES	: VIIIC1
R	VTXOUT	USES	: VTXCOM
R	VTXPRM	USES	: VTXCOM
R	WAKPRM	USES	: DTETHE VTXCOM
R	WAKPR1	USES	: DTETHE WAKP01
R	WAK001	USES	: WAKR01 DTETHE
R	WAK003	USES	: WAKR01 WAKP01 LSTR02 LSTR01 DTETHE CRPP01
R	ZEROAL	USES	: WORK
		USES	: AIRDAT AIRCDF AIRCDM AIRALZ

Figure 3D: UCAP Labeled Common Area Reference Listing (cont)

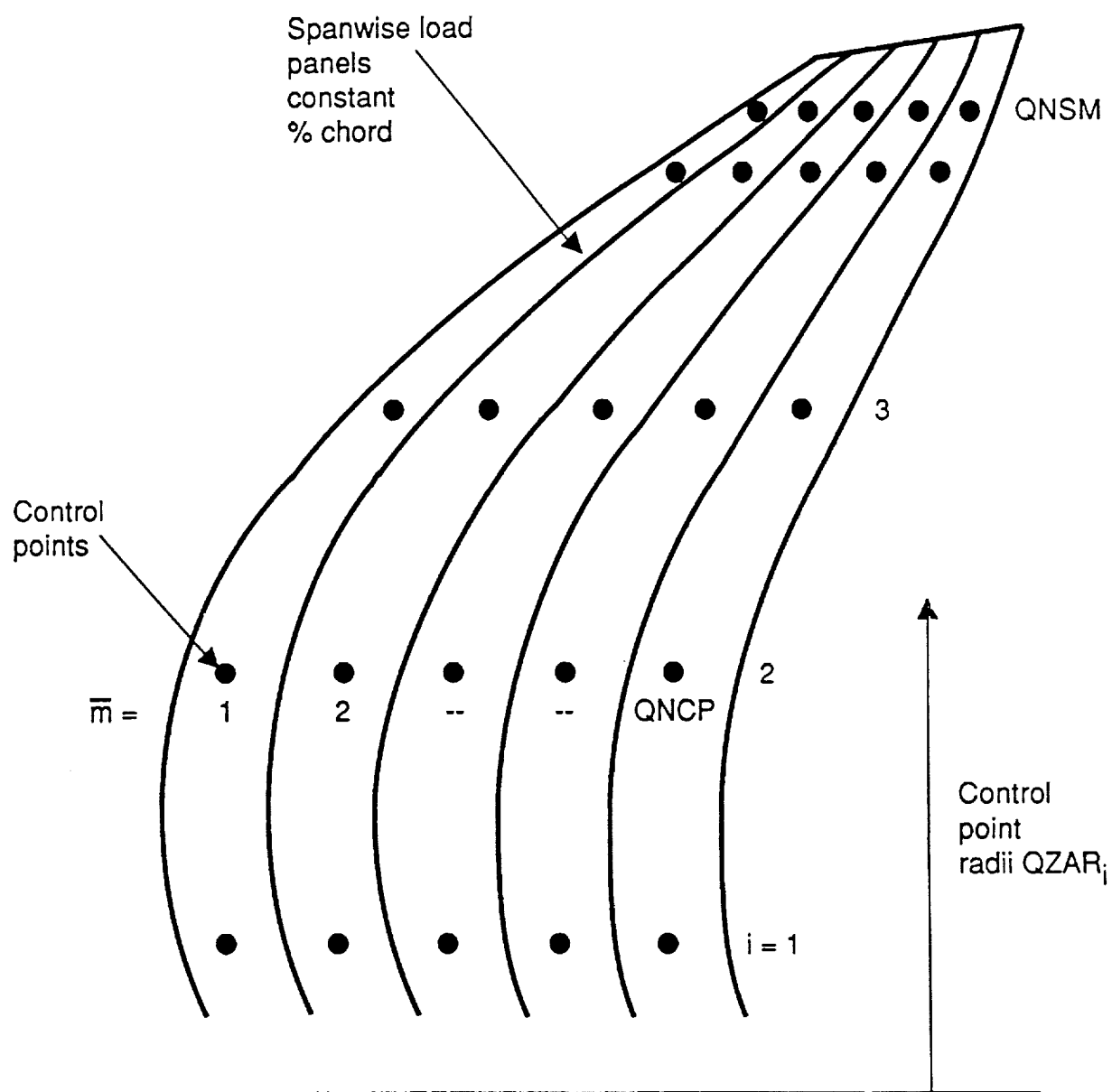


Figure 4 Spanwise load panels and control points

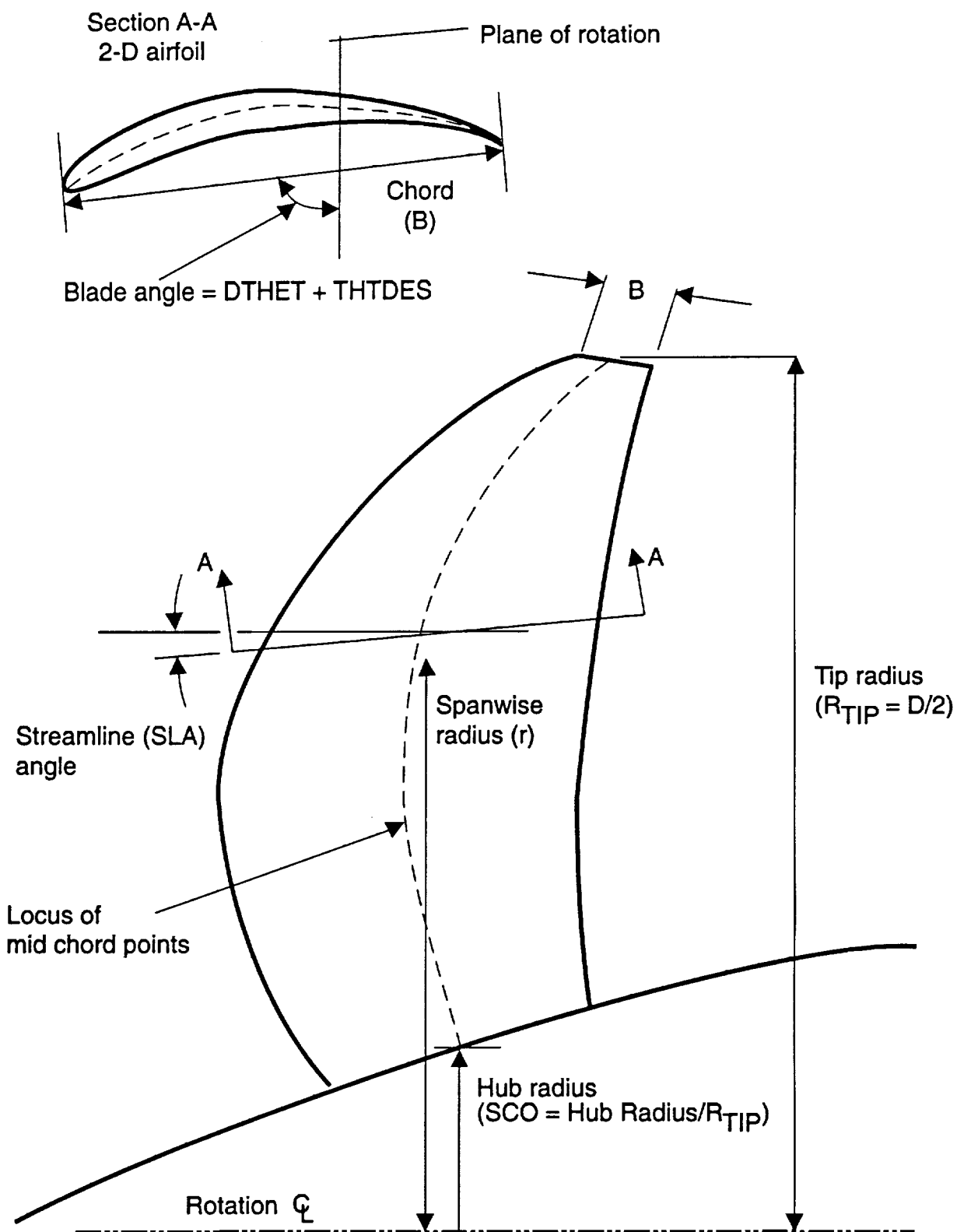


Figure 5 Blade geometry nomenclature (2-D coords)

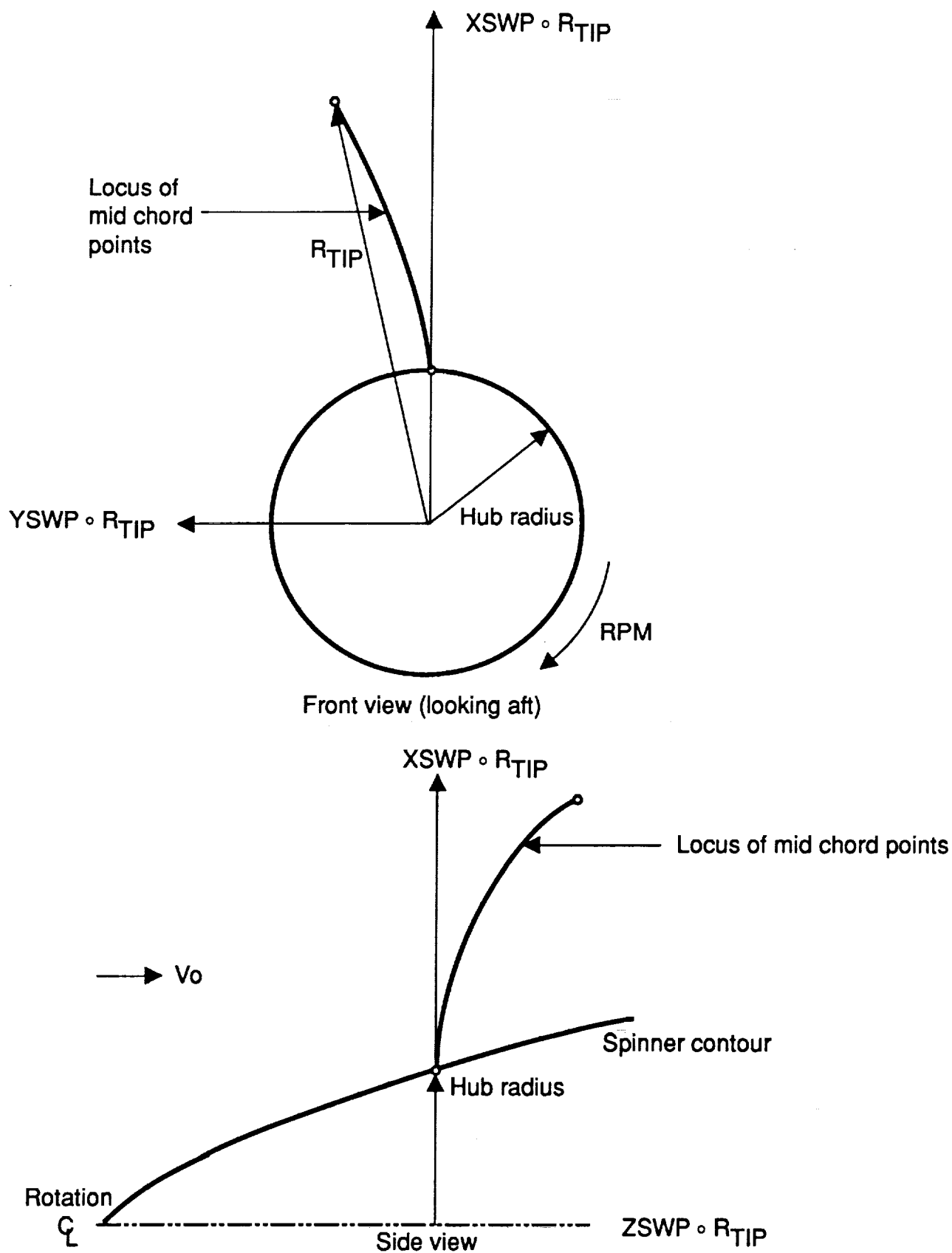


Figure 6 Blade geometry nomenclature (2-D coords)

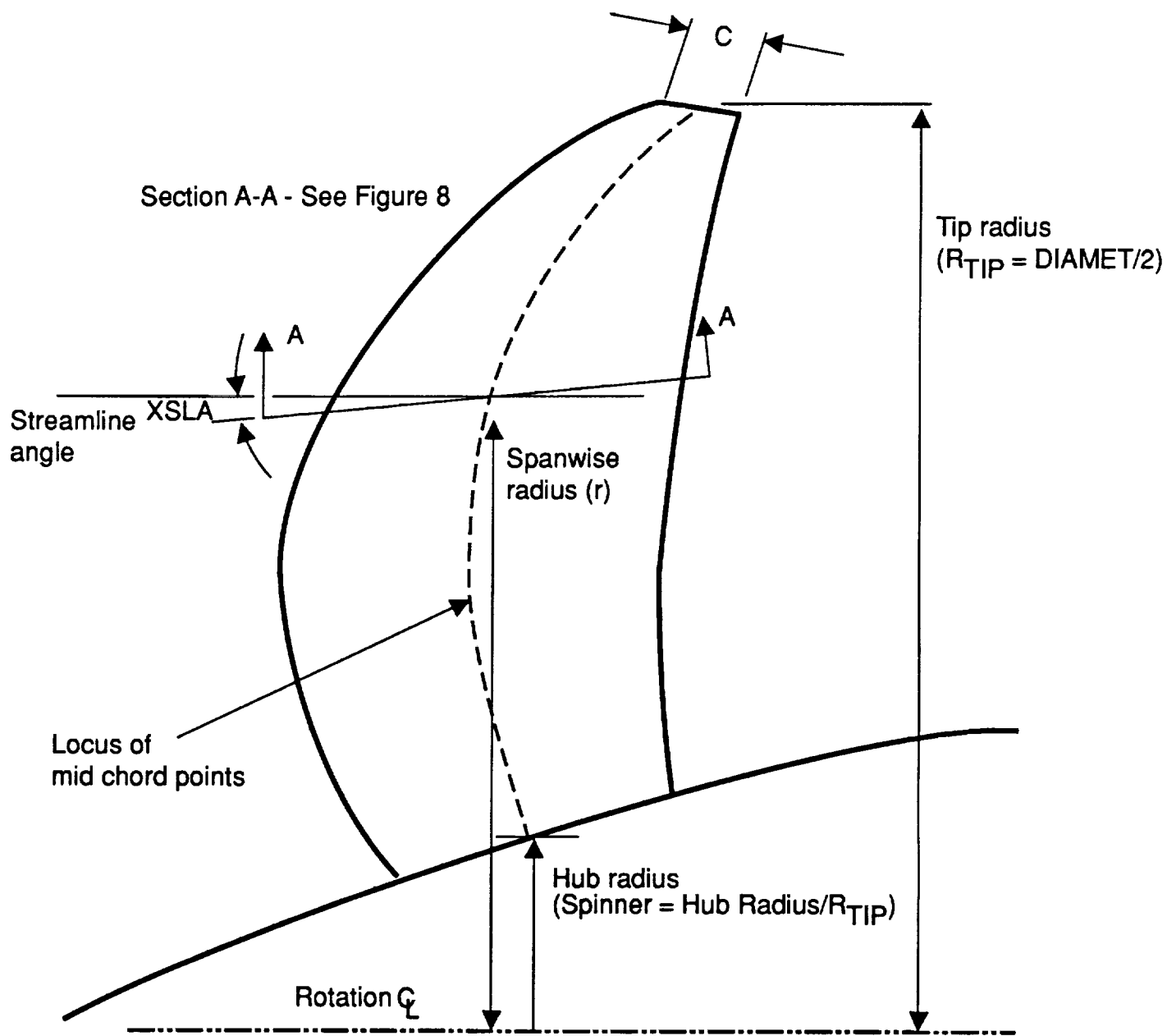


Figure 7 Blade geometry nomenclature (RXY coord)

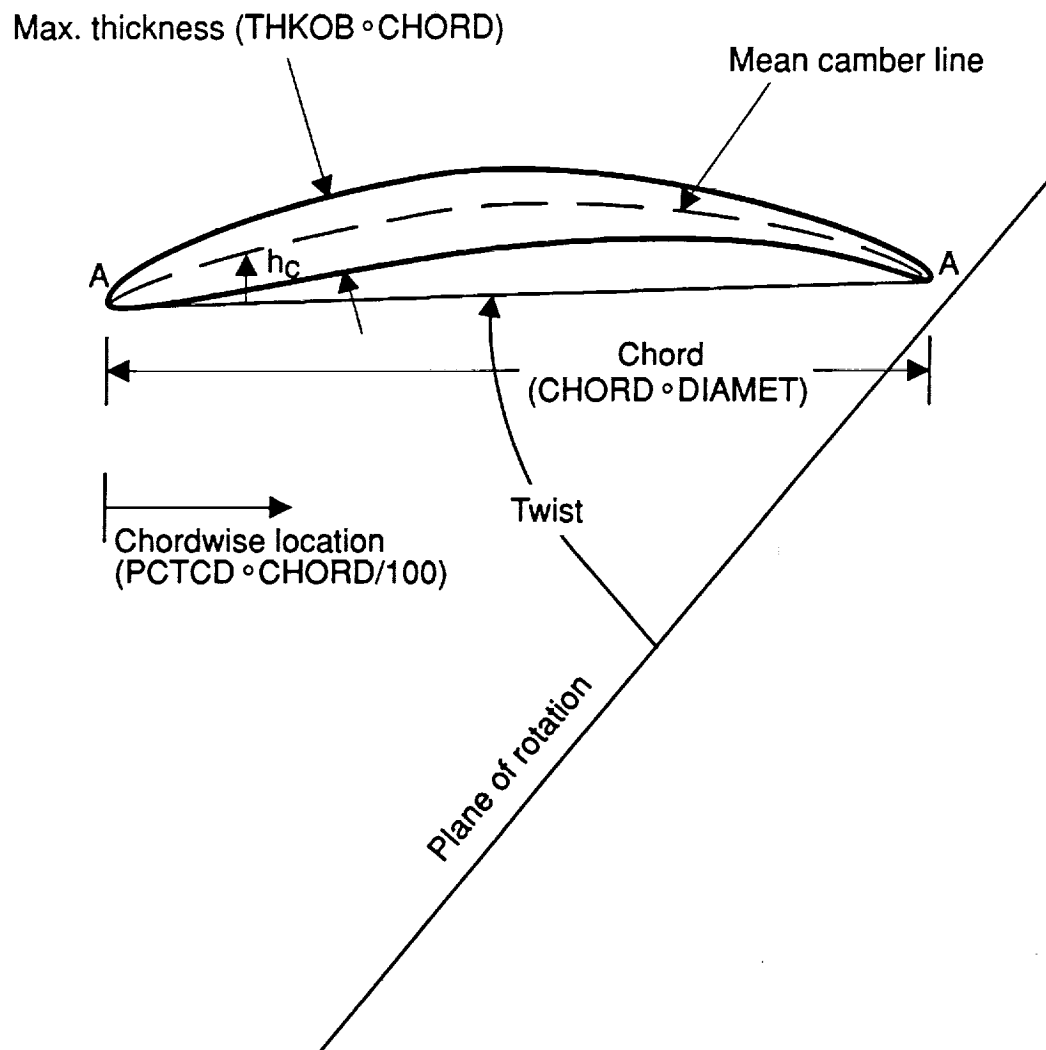


Figure 8 Blade geometry nomenclature (RXY coord)

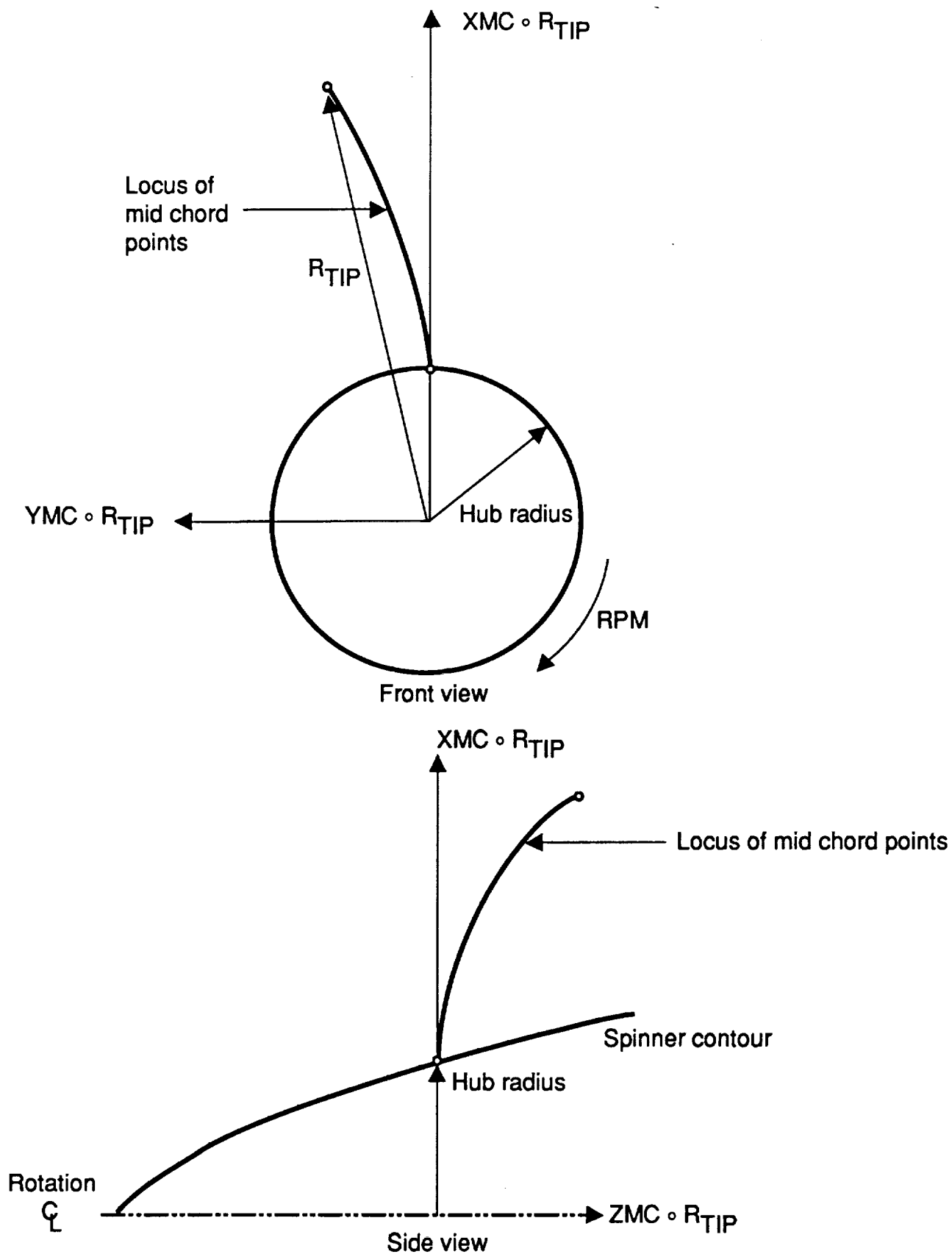


Figure 9 Blade geometry nomenclature (RXY coord)

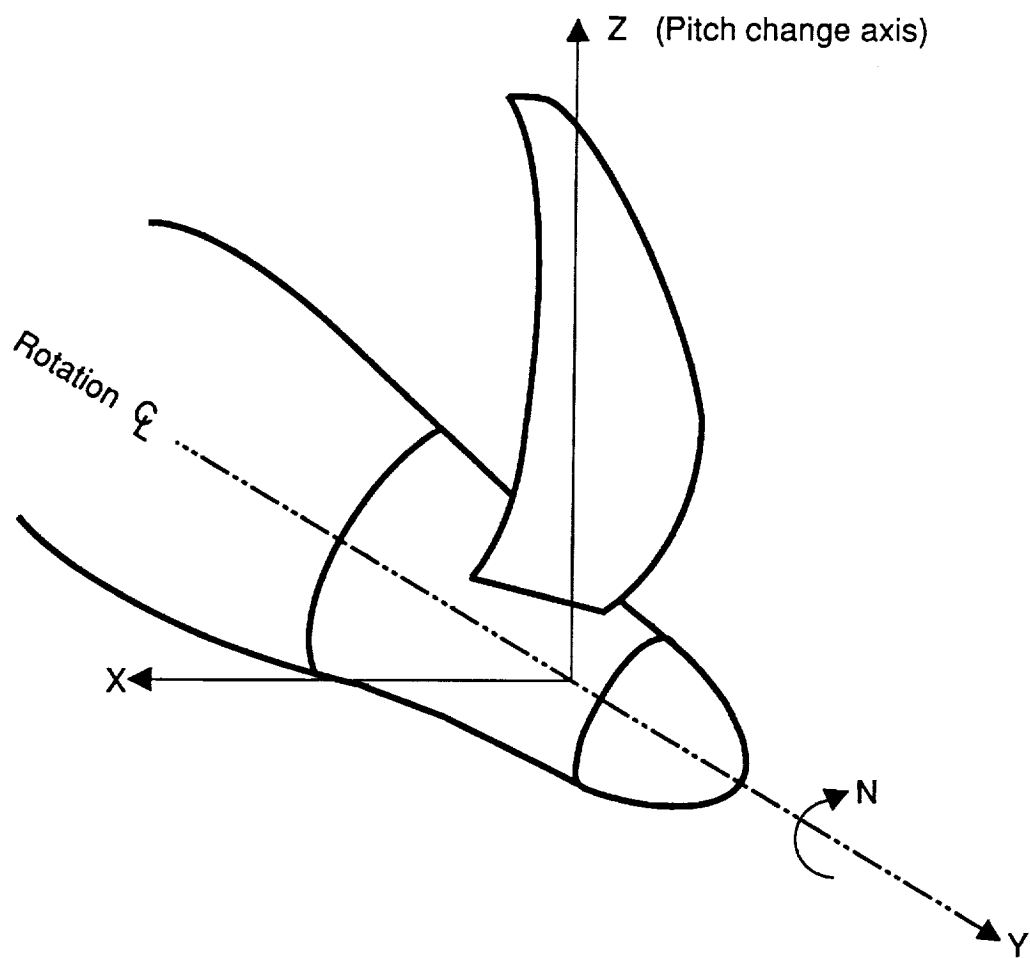


Figure 10 Blade geometry nomenclature (XYZ coords)

READ / PRINT ALL INPUT DATA : INPTRW INPUTRW TIME: 17:00.20 DATE: 1/15/92 UCAP --- NASA 4

 HEADER (CR-2)

UCAP FOR CR-2 INPUT -- R252INPT.DAT
 HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

END

AIRPARMS

L001 1 24.0 5.0

END

VELGRADS

L002 0.0

END

RUNPARMS

L001 1.0 56.18 .9662 1.4601 .265

L016 1.4522

END

CRPPARMS

L001 1.0 1.0 0.257 20.0 0.01

L006 2.0 1.0

END

INTERPRM

L001 1.0

END

NOIZPARM

L 1 1.0 4. 6.12

L 9 7. 0.

L 31 6.360 4.645 2.573 0.417

-1.447 -4.112 -8.773

END

BLADEGE01(2-DCOFWD)

C CRP-X2 : BLADING DEFINITION AGREES WITH "BLADE DESIGN DATA BASE"

C FRONT

C THIS IS GEOMETRIC VERSION OF BLADE

C THIS BLADE HAS 65/CA AND 16 SERIES AIRFOILS

C

C DATE :06/14/88

C

L001 1.0

L031 6.0 2.0467 0.245

L41 0.2553 0.2965 0.3665 0.4594 0.5668 0.6792 0.7866 0.8795 0.949F 4.000

L51 0.1580 0.1050 0.0664 0.0490 0.0380 0.0301 0.0248 0.0218 0.0201 0.020

L61 0.1650 0.1717 0.1840 0.1980 0.2040 0.1952 0.1740 0.1420 0.1050 .0635

L71 0.0500 0.0690 0.0930 0.1320 0.1710 0.2070 0.2300 0.2310 0.2200 .2000

L81 23.500 21.400 17.790 13.000 7.600 2.598 -1.500 -4.300 -6.150 -7.59

L91 4. 4. 2. 1. 1. 1. 1. 1. 1. 1.

L346 2.0 55.46 48.87 1.0

L381 5.03 4.22 3.42 2.69 1.98 1.35 0.85 0.468 0.21 0.02

L711 .25520 .29627 .36598 .45068 .56651 .67910 .78403 .87114 .9352 .9811

L721 -.0830 -.0097 -.0195 -.0257 -.0180 .0115 .0635 .1210 .1640 .1936

L731 -.0055 -.0165 -.0370 -.0417 -.0251 .01367 .06978 .1220 .15875 .1832

L741 4. 4. 2. 1. 1. 1. 1. 1. 1. 1.

-L950 22

L951 0.100 0.300 0.400 0.500 0.550 0.600 0.650 0.700 0.750 0.800

0.825 0.850 0.875 0.900 0.925 0.950 0.960 0.970 0.980 0.990

Figure 11 : Input Echo

```

0.995 1.000
END
LSTPARMS(FWD )
L001 1.0 10.0 0.02 0.0 1024.
C MM PART1 - 0 TO CREATE, 3 TO READ
L020 1.0
END
VORTPARM(FWD )
L001 1.0
END
BLADEGE012(DCOAFT)
C CRP-X2 : BLADING DEFINITION AGREES WITH "BLADE DESIGN DATA BASE"
C REAR
C THIS IS GEOMETRIC VERSION OF BLADE
C THIS BLADE HAS 65/CA AND 16 SERIES AIRFOILS
C DATE :06/14/88
C
L001 1.0
L31 5. 2.0467 .245
L41 0.2553 0.2965 0.3665 0.4594 0.5668 0.6792 0.7866 0.8795 0.9495 1.000
L51 0.1580 0.1830 0.0664 0.0490 0.0300 0.0301 0.0248 0.0218 0.0204 0.020
L61 0.1650 0.1717 0.1840 0.1980 0.2040 0.1952 0.1740 0.1420 0.1060 0.635
L71 0.0500 0.0690 0.0930 0.1320 0.1710 0.2070 0.2300 0.2310 0.2200 0.2000
L81 23.500 21.400 17.790 13.000 7.600 2.598 -1.508 -4.300 -6.150 -7.59
L91 4. 4. 2. 1. 1. 1. 1. 1. 1. 1.
L346 4. 4. 2. 2.0 55.46 48.54 1.0
L381 5.03 4.22 3.42 2.69 1.98 1.35 0.85 0.468 0.21 0.02
L711 .25528 .29627 .36598 .45868 .56651 .67910 .78403 .87114 .9352 .9811
L721 -.0030 -.0097 -.0195 -.0257 -.0180 .0115 .0635 .1210 .1640 .1936
L731 -.0055 -.0165 -.0370 -.0417 -.0251 .01367 .06978 .1220 .15875 .1832
L741 4. 4. 4. 2. 1. 1. 1. 1. 1. 1.
L950 22
L951 0.100 0.300 0.400 0.500 0.550 0.600 0.650 0.700 0.750 0.800
0.825 0.850 0.875 0.900 0.925 0.950 0.960 0.970 0.980 0.990
0.995 1.000
END
LSTPARMS(AFT )
L001 1.0 10.0 0.02 0.0 1024.
C MM PART1 - 0 TO CREATE, 3 TO READ
L020 3.0
END
VORTPARM(AFT )
L001 1.0
END
AEROEXEC(EXECCASE)
NOIZEC(EXECCASE)
ENDCASE
ENDJOB

```

Figure 11 : Input Echo (continued)


```

RUNPARMS INPUT / OUTPUT      : RUNPRH      RUNPARMS      TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4
*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
DEBUG (001)      1.0
TEMP.FDEG (002)      56.2
RHO/RHO 0 (003)      0.9662
FWD ADV. RATIO (004)      1.460
AFT ADV. RATIO (016)      1.452
MACH NO. (005)      0.265

```

Figure 12: RUNPARMS output

```

CPPPARMS INPUT/OUTPUT.....SRI  CRPPRM  CRPPARMS  TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4
*****
UCAP FOR CR-2 INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
CRPBUG SWITCH (001) 1.
CRP/SRP SWITCH (002) 1.
ROTOR SPACING (003) 0.2570
ITER. LIMIT (004) 20.
TOLERANCE (005) 0.01000
FWD->AFT HARN. (006) 2.
AFT->FWD HARN. (007) 1.
*****

```

Figure 13: CRPPARMS output

```

AIRFOIL DATA OPTIONS INPUT      : AIRPRM      AIRPARMS      TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA      4
*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP HATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP HATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
DEBUG      (001)      1.
AIRF.NUMB.      (002)      24.
AIRF.TYP.      (003)      5.
AIR. CL/CD      (013)      0.0000
CD MULT.      (015)      0.0000
DELTA CD      (017)      0.0000
*****

```

Figure 14: AIRPARMS output

```

2-D COORDINATE INPUT---FORWARD: BLDG11  BLADEGEO 2-DCOFWD  TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL

*****
DEBUG (001) 1.
BLADN (031) 6.
DIAMETER (032) 2.05
SCO (033) 0.2450
SWEET TYPE (346) 2.
DESIGN ANGLE (347) 55.46
RUNNING ANGLE (348) 48.87
TYPE CUT (349) 1.00
X (041) 0.2553 0.2965 0.3665 0.4594 0.5668 0.6792 0.7866 0.8795 0.9495 1.0000
(051) 0.1150 0.1030 0.0664 0.0490 0.0300 0.0301 0.0248 0.0218 0.0204 0.0200
(061) 0.1650 0.1717 0.1848 0.1980 0.2040 0.1952 0.1740 0.1420 0.1060 0.0635
(071) 0.0500 0.0690 0.0930 0.1320 0.1710 0.2070 0.2300 0.2310 0.2200 0.2000
DELTA THETA (081) 23.5000 21.4000 17.7900 13.0000 7.6000 2.5980 -1.5000 -4.3000 -6.1500 -7.5900
XSMP (711) 0.2553 0.2963 0.3660 0.4587 0.5665 0.6791 0.7840 0.8711 0.9352 0.9811
YSMP (721) -0.0030 -0.0097 -0.0195 -0.0257 -0.0180 0.0115 0.0635 0.1210 0.1640 0.1936
ZSMP (731) -0.0055 -0.0165 -0.0370 -0.0417 -0.0251 0.0137 0.0698 0.1220 0.1587 0.1832
AIRFOIL TYP (741) 4. 4. 4. 2. 1. 1. 1. 1. 1. 1.
NO.OF ZCHORDS (900) 11.
LIST -ZCHORDS (901) 0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00 90.00
100.00
NO.OUT STATIONS(950) 22.
LIST - STATIONS(951) 0.1000 0.3000 0.4000 0.5000 0.5500 0.6000 0.6500 0.7000 0.7500 0.8000
0.8250 0.8500 0.8750 0.9000 0.9250 0.9500 0.9600 0.9700 0.9800 0.9900
0.9950 1.0000

```

Figure 15: BLADEGEO output (2-DCOFWD: 2-D coordinates, forward rotor)

```

AERO PANEL INPUT PARMS--FORWARD: LSTPRM      LSTPARMS FWD      TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA      4
*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER HATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP HATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP HATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
LSTBUG      (001)      1.
NCP      (002)      10.
DR      (003)      0.020
NSH      (004)      8.
N      (005)      1024.
DELTAX      (006)      0.0040
MODOP      (007)      4.
TOLINF      (008)      0.000100
TOLINT      (009)      0.001000
TOLSUH      (010)      0.005000
IH1      (011)      20.
IH2      (012)      60.
IH3      (013)      10.
ITABK      (014)      8.
ITABT      (015)      9.
INT4      (016)      0.
PRINT      (017)      0.
PRIN1      (018)      0.
PRIN2      (019)      0.
PART1      (020)      1.
Q      (021)      0.0000
K      (022)      0.
KDOWN      (023)      0.0250
KSTART      (024)      0.0100
HH4      (025)      5.
HBLEND      (026)      0.90
N0      (027)      1024.
NBOPT      (028)      2.
ITHDN      (029)      10.
ZAR      (030)      0.2000
CONTPY      (031)      0.5000
KARRY      (032)      0.0000
INRES      (033)      0.0020
0.4500      0.5500      0.6500      0.7500      0.8500      0.9500
0.5000      0.5000      0.5000      0.5000      0.5000      0.5000
0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
0.0020      0.0020      0.0020      0.0020      0.0020      0.0020

```

Figure 16: LSTPARMS output

```

RUN PARAMETERS FOR NOISE CALC. : NOZPRM      NOIZPARM      TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA  4
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER HATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP HATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP HATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
PRINT PARMS      (001)      1.0
NEAR OR FAR      (002)      0.0
# HARMONICS      (003)      4.0
HIN. OBS. DIST.(004)      6.12
# AXIAL LOCS.    (009)      7.0
VIS. OR RET.     (010)      0.0
VISUAL X         (011)      0.0
RETARDED X       (031)      0.00      0.00      0.00      0.00      0.00      0.00      0.00
ZJHIN1           (051)      0.0
ZJH1             (052)      0.0
ZJHIN2           (053)      0.0
ZJH2             (054)      0.0
OUTPUT FILE #    (055)      6.0
START HARMONIC   (056)      1.0
HARM. INCREMENT  (057)      1.0
NOT USED         (058)      0.0
BL-WAKE H/B      (059)      1.0
LOAD DIAGNOSTIC  (060)      0.0
FULL DIAGNOSTIC  (061)      0.0
PUNCH DB LEVELS  (062)      0.0
KK,FREQ INTEG.   (063)      0.0
EXTEND FREQ      (064)      0.0
ZKHIN, CALC KK   (065)      0.0
ZOMEGA, CALC KK  (066)      0.0
EXTRA PRINT OPT  (067)      0.0
INSTANT QUAD     (068)      0.0
AZI. DIREC, FWD  (069)      90.0
AZI. DIREC, AFT  (070)      90.0
AIRFOIL TYPE     (071)      1.0      1.0      1.0      1.0      1.0      1.0      1.0

```

Figure 17: NOIZPARM output

AXIS. NACELLE AXIAL VEL. MM : VEL001 VELGRADS TIME HH:MM:SS DATE : MM/DD/YY UAAP --- NASA 1

SAMPLE PERFORMANCE CALCULATION FOR SRP VERSION OF UAAP

J = 3.10, H = 0.70, BETA 3/4 R = 55.45 DEG.

EDGE VORTEX GIVES LIFT, NOT RADIAL FORCE
FAR FIELD NOISE

VELOCITY /V	(+25)	254.510	259.300	241.400	241.270	259.810	258.080	256.560	255.080	253.900	253.150
RAD.LOC /R	(025)	252.510	252.040	251.710	251.550	9.623	11.066	12.434	14.402	16.816	19.042
AXL.LOC-Z/R	(+25)	21.588	6.282	7.169	8.280	-6.915	-6.947	-6.870	-6.658	-6.235	-5.811
VELOCITY /V	(+25)	-4.490	-6.560	-6.698	-6.825	260.980	259.150	257.380	255.610	254.250	253.430
RAD.LOC /R	(025)	252.780	252.230	251.850	251.700	9.717	11.175	12.718	14.673	16.874	19.089
AXL.LOC-Z/R	(+25)	21.624	6.427	7.289	8.383	-6.043	-6.049	-5.949	-5.774	-5.403	-5.025
VELOCITY /V	(+25)	-5.710	-5.763	-5.890	-5.984	258.910	258.000	256.800	255.390	254.220	253.500
RAD.LOC /R	(025)	252.970	252.400	252.020	251.860	9.798	11.245	12.779	14.727	16.920	19.124
AXL.LOC-Z/R	(+25)	21.653	6.402	7.416	8.481	-5.178	-5.152	-5.044	-4.886	-4.577	-4.248
VELOCITY /V	(+25)	-4.930	-4.978	-5.070	-5.145	253.500	253.530	253.450	253.210	252.860	252.550
RAD.LOC /R	(025)	252.420	252.270	252.060	251.970	9.876	11.313	12.838	14.778	16.963	19.163
AXL.LOC-Z/R	(+25)	21.682	6.789	7.550	8.580	-4.307	-4.255	-4.165	-4.005	-3.752	-3.471
VELOCITY /V	(+25)	-4.150	-4.185	-4.251	-4.299	247.990	248.110	248.650	249.450	250.240	250.790
RAD.LOC /R	(025)	251.400	251.840	252.040	252.100	9.973	11.397	12.915	14.849	17.030	19.225
AXL.LOC-Z/R	(+25)	21.734	6.911	7.669	8.689	-3.459	-3.418	-3.305	-3.106	-2.718	-2.344
VELOCITY /V	(+25)	-3.170	-3.230	-3.342	-3.414	247.570	247.910	248.590	249.500	250.440	251.230
RAD.LOC /R	(025)	250.510	251.440	249.320	247.490	10.027	11.450	12.969	14.907	17.090	19.282
AXL.LOC-Z/R	(+25)	21.789	6.922	7.703	8.738	-2.592	-2.450	-2.494	-2.170	-1.669	-1.220
VELOCITY /V	(+25)	-2.030	-2.157	-2.358	-2.484	244.870	246.760	248.220	249.670	250.890	251.740
RAD.LOC /R	(025)	231.000	234.410	238.870	242.240	10.152	11.563	13.069	14.990	17.155	19.333
AXL.LOC-Z/R	(+25)	21.827	7.063	7.850	8.877	-1.745	-1.784	-1.637	-1.344	-0.890	-0.485
VELOCITY /V	(+25)	-0.093	0.180	0.184	0.194	255.380	255.520	255.410	255.180	254.890	254.540
RAD.LOC /R	(025)	249.000	251.240	253.540	255.770	10.249	11.649	13.142	15.049	17.202	19.371
AXL.LOC-Z/R	(+25)	21.857	7.196	7.971	8.986	-0.898	-0.917	-0.783	-0.523	-0.124	0.246
VELOCITY /V	(+25)	0.604	0.820	0.825	0.831	257.710	257.080	256.510	255.970	255.560	255.150
RAD.LOC /R	(025)	240.060	259.830	259.180	258.430	10.342	11.734	13.219	15.114	17.255	19.413
AXL.LOC-Z/R	(+25)	21.888	7.317	8.081	9.087	-0.047	-0.041	0.072	0.293	0.654	0.989
VELOCITY /V	(+25)	1.292	1.470	1.472	1.476	255.590	255.770	255.920	256.010	255.880	255.560
RAD.LOC /R	(025)	254.910	254.090	253.430	253.000	10.450	11.829	13.301	15.181	17.304	19.450
AXL.LOC-Z/R	(+25)	21.915	7.450	8.207	9.205	0.800	0.826	0.927	1.115	1.420	1.721
		1.050	0.987	0.874	0.821						
		1.989	2.110	2.111	2.113						

Figure 18 VELGRADS output (continued)

VELOCITY /V	(+25)	237.910	240.570	244.320	247.690	250.520	252.580	253.950	254.850	255.080	254.930
RAD.LOC /R	(025)	254.540	253.990	253.490	253.100	10.537	11.911	13.872	15.238	17.349	19.483
AXL.LOC-Z/R	(+25)	21.938	24.622	27.617	31.715	1.647	1.693	1.781	1.938	2.195	2.454
VELOCITY /V	(+25)	21.020	1.773	1.688	1.649	243.990	247.460	249.850	251.690	252.790	253.300
RAD.LOC /R	(025)	224.980	228.480	233.830	239.220	243.990	247.460	249.850	251.690	252.790	253.300
AXL.LOC-Z/R	(+25)	253.610	253.690	253.540	253.210	10.864	12.155	13.551	15.356	17.426	19.533
VELOCITY /V	(+25)	21.970	24.645	27.636	31.731	3.053	3.072	3.093	3.154	3.266	3.377
RAD.LOC /R	(025)	253.070	253.740	254.730	255.440	255.740	255.650	255.380	255.050	254.730	254.420
AXL.LOC-Z/R	(+25)	254.130	253.920	253.660	253.300	11.099	12.327	13.677	15.444	17.482	19.570
VELOCITY /V	(+25)	21.996	24.665	27.652	31.743	4.250	4.250	4.250	4.250	4.250	4.250
RAD.LOC /R	(025)	280.180	277.580	273.460	269.040	264.870	261.610	259.210	257.230	255.870	255.040
AXL.LOC-Z/R	(+25)	254.950	254.040	253.750	253.410						

Figure 18 VELGRADS output

PROPELLER WAKE ANALYSIS INPUT (MAXPRM) WAKEPARM TIME (HH:MM:SS DATE) (MM/DD/YY UAAP) --- NASA 1

SAMPLE PERFORMANCE CALCULATION FOR SRP VERSION OF UAAP

BLADE RQH
J = 3.10, M = 0.70, BETA 3/4 R = 55.45 DEG.

EDGE VORTEX GIVES LIFT, NOT RADIAL FORCE
FAR FIELD NOISE

```

*****
DEBUG (001) 1.0000
K (002) 0.0500
ADVR (003) 0.00
NOR (004) 1.
NPX (005) 0.
IPLOT (006) 1.
NPSKN (008) 1.000000
TOL (009) 0.000100
M11 (010) 0.
TOL1 (012) 0.001000
LAST (013) 20.
ZO (016) 0.700000
NORM (017) 0.5000
ADPT (018) 1.0000
ILFP (019) 0.
IPRT (020) 0.
M12 (021) 0.
C (022) 0.
IVAK (023) 0.
INK (024) 0.
NCS (050) 1.
M1U (051) 0.
M1V (052) 98.
M1W (053) 98.
FPMH (054) 0.0300
ROUT (351) 0.7000
XBAR (701) 0.3910

```

Figure 20: WAKEPARM output

INTERPRM INPUT/OUTPUT.....SBR: INTERPRM INTERPRM TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

```

*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER HATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP HATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP HATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL

```

```

*****
DEBUG SWITCH (001) 1.
K (002) 0.0500
Z0 (003) 0.7000
ZNORM (004) 0.5000
ADPT (005) 1.
IVNK (006) 1.
FPIW (007) 0.0100
NPSKN (008) 1.
TOL (009) 0.00010
TOL1 (010) 0.00100
MH1 (011) 99.
IPLOT (015) 0.
IPRT (016) 0.

```

VARIABLE DESCRIPTIONS ARE SAME AS FOR WAKEPARH.

Figure 21: INTERPRM output

```

SUBROUTINE: GETXMB,  DEBUG PRINTOUT STATUS: T
              ARGUMENT LIST INPUT ITEMS
FORWARD ROTOR DIAMETER:
AFT ROTOR DIAMETER:
FORWARD ROTOR ADVANCE RATIO:
AFT ROTOR ADVANCE RATIO:
MAX. NUMBER CHORDWISE PANELS:
MAX. NUMBER SPANWISE PANELS:
ROTOR TO ROTOR SPACING:

```

```

2.0467
2.0467
1.4522
1.4601
10
10
0.2570 (NORMALIZED BY FORWARD ROTOR DIAMETER)

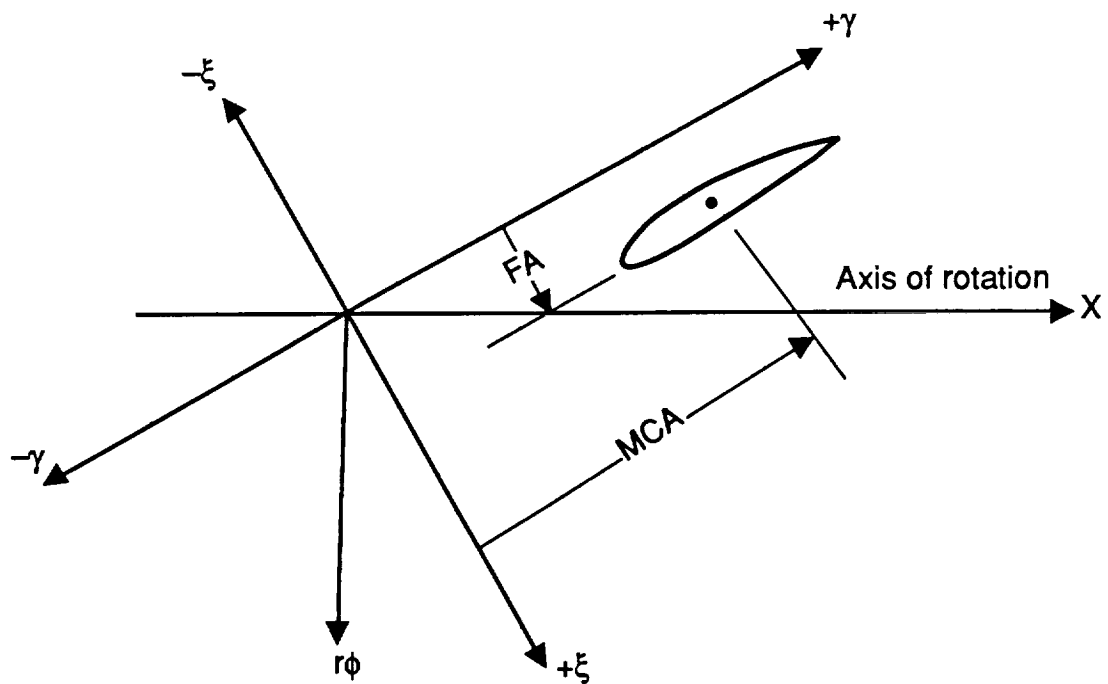
```

Figure 22: AEROEXEC output (GETXMB section 1)

NUMBER OF INPUT RADII: 22.		ROTOR: FORWARD		FA
STATION	RADIUS	CHORD	TWIST	HCA
1	0.100	0.1747	70.004	0.01746
2	0.300	0.1747	70.004	-0.01012
3	0.400	0.1897	65.005	-0.02366
4	0.500	0.2006	59.982	-0.02244
5	0.550	0.2026	57.477	-0.02277
6	0.600	0.2015	55.096	-0.0240
7	0.650	0.1971	52.872	-0.01750
8	0.700	0.1900	50.778	-0.00980
9	0.750	0.1805	48.846	0.00003
10	0.800	0.1678	47.124	0.00253
11	0.825	0.1601	46.344	0.00584
12	0.850	0.1516	45.609	0.00956
13	0.875	0.1422	44.912	0.01146
14	0.900	0.1319	44.236	0.01342
15	0.925	0.1202	43.576	0.01546
16	0.950	0.1061	42.912	0.01762
17	0.960	0.0996	42.635	0.01986
18	0.970	0.0924	42.352	0.02216
19	0.980	0.0845	42.064	0.02310
20	0.990	0.0759	41.776	0.02403
21	0.995	0.0713	41.636	0.02498
22	1.000	0.0665	41.502	0.02593
				0.02641
				0.02689

NUMBER OF SPAN-WISE MODES (CONTROL POINTS): 8
NUMBER OF CHORDWISE CONTROL POINTS: 10

Figure 23: AEROEXEC output (GETXMB section 2)



Mid chord alignment (MCA) and face alignment (FA)
(positive as shown)

γ is the path the pitch change axis has traveled along the advance helix

ζ is normal to γ and r

Figure 24 Blade section definition and definition of advance coordinate, γ .

NUMBER	RADIUS	CHORD	PHI	THIST	HCA	FA	%CHORD
--------	--------	-------	-----	-------	-----	----	--------

01	0.2000	0.1747	66.717	70.004	0.00367	-0.00060	0.50000	MBAR	HU	XMBAR	DELTA-PHI
								01	001	-0.6555	-95.5010
								02	002	-0.6226	-88.0090
								03	003	-0.5898	-80.5170
								04	004	-0.5570	-73.0250
								05	005	-0.5242	-65.5330
								06	006	-0.4913	-58.0410
								07	007	-0.4585	-50.5489
								08	008	-0.4257	-43.0569
								09	009	-0.3928	-35.5649
								10	010	-0.3600	-28.0729

02	0.3500	0.1022	53.018	67.504	-0.01609	-0.00076	0.50000	HBAR	HU	XHBAR	DELTA-PIH1
								01	011	-0.6934	-99.3447
								02	012	-0.6597	-92.8896
								03	013	-0.6261	-86.4346
								04	014	-0.5924	-79.9796
								05	015	-0.5587	-73.5246
								06	016	-0.5251	-67.0696
								07	017	-0.4914	-60.6146
								08	018	-0.4577	-54.1596
								09	019	-0.4241	-47.7046
								10	020	-0.3904	-41.2496

03	0.4500	0.1951	45.925	62.494	-0.02305	-0.00250	0.50000	MBAR	HU	KMBAR	DELTA-PHI
								01	021	-0.7064	-101.5087
								02	022	-0.6718	-94.9230
								03	023	-0.6371	-88.3372
								04	024	-0.6025	-81.7514
								05	025	-0.5679	-75.1656
								06	026	-0.5333	-68.5798
								07	027	-0.4987	-61.9940
								08	028	-0.4641	-55.4082
								09	029	-0.4294	-48.8224
								10	030	-0.3948	-42.2366

04	0.5500	0.2026	40.199	57.477	-0.01758	-0.00248	0.54J00	M _{*,R}	HJ	XMBAR	DELTA-PIII
								01	031	-0.6942	-98.7254
								02	032	-0.6601	-92.2209
								03	033	-0.6259	-85.7164
								04	034	-0.5917	-79.2119
								05	035	-0.5576	-72.7073
								06	036	-0.5234	-66.2028
								07	037	-0.4892	-59.6983
								08	038	-0.4551	-53.1938
								09	039	-0.4209	-46.6893
								10	040	-0.3867	-40.1847

126

05	0.6500	0.1971	35.566	52.872	0.00102	0.00003	0.50000	HBAR 01 02 03 04 05 06 07 08 09 10	MU 041 042 043 044 045 046 047 048 049 050	XMBAR -0.6542 -0.6227 -0.5913 -0.5599 -0.5285 -0.4970 -0.4656 -0.4342 -0.4028 -0.3713	DELTA-PHI -90.3771 -84.3850 -78.3930 -72.4009 -66.4089 -60.4168 -54.4248 -48.4327 -42.4407 -36.4486
06	0.7500	0.1805	31.786	48.846	0.03218	0.00584	0.50000	HBAR 01 02 03 04 05 06 07 08 09 10	MU 051 052 053 054 055 056 057 058 059 060	XMBAR -0.5925 -0.5653 -0.5381 -0.5110 -0.4838 -0.4566 -0.4294 -0.4022 -0.3750 -0.3479	DELTA-PHI -77.8969 -72.7129 -67.5288 -62.3447 -57.1607 -51.9766 -46.7925 -41.6085 -36.4244 -31.2403
07	0.8500	0.1516	28.669	45.609	0.07183	0.01342	0.50000	HBAR 01 02 03 04 05 06 07 08 09 10	MU 061 062 063 064 065 066 067 068 069 070	XMBAR -0.5190 -0.4973 -0.4757 -0.4540 -0.4324 -0.4107 -0.3890 -0.3674 -0.3457 -0.3240	DELTA-PHI -63.1348 -59.0203 -54.9058 -50.7913 -46.6768 -42.5623 -38.4478 -34.3333 -30.2188 -26.1043
08	0.9500	0.1061	26.069	42.912	0.11137	0.02216	0.50000	HBAR 01 02 03 04 05 06 07 08 09 10	MU 071 072 073 074 075 076 077 078 079 080	XMBAR -0.4413 -0.4269 -0.4124 -0.3980 -0.3835 -0.3691 -0.3546 -0.3402 -0.3257 -0.3113	DELTA-PHI -48.0297 -45.3008 -42.5719 -39.8430 -37.1142 -34.3853 -31.6564 -28.9275 -26.1986 -23.4697

FORWARD ROTOR-INNER WAKE POINTS.	QUANTITY: 06
NUMBER	R/R
01	0.2000
02	0.3500
03	0.4500
04	0.5500
05	0.6500
06	0.7500
07	0.8500
08	0.9500

Figure 26: AEROEXEC output (GETXMB section 4)

SUBROUTINE LESWP DEBUG PRINTOUT											
N	BLADE STA.	MCA/D	CHORD/DIA	L.E.	SHEEP	N	BLADE STA.	MCA/D	CHORD/DIA	L.E.	SHEEP
1	0.100	0.0175	0.1747	-15.4217	2	0.300	-0.0101	0.1747	-17.9596		
3	0.400	-0.0237	0.1897	-14.1844	4	0.500	-0.0224	0.2006	-0.2869		
5	0.550	-0.0176	0.2026	13.7262	6	0.600	-0.0098	0.2015	23.1390		
7	0.650	0.0010	0.1971	31.4593	8	0.700	0.0151	0.1900	30.2880		
9	0.750	0.0322	0.1805	43.5563	10	0.800	0.0515	0.1678	46.5685		
11	0.825	0.0616	0.1601	48.6969	12	0.850	0.0718	0.1516	49.6258		
13	0.875	0.0820	0.1422	50.2498	14	0.900	0.0921	0.1319	50.9323		
15	0.925	0.1018	0.1202	52.1766	16	0.950	0.1114	0.1061	53.4105		
17	0.960	0.1151	0.0996	55.0169	18	0.970	0.1188	0.0924	56.0797		
19	0.980	0.1224	0.0845	57.1878	20	0.990	0.1261	0.0759	58.0495		
21	0.995	0.1279	0.0713	58.9631	22	1.000	0.1297	0.0665	59.2784		

Figure 27: AEROEXEC output (GETXMB section 5, LESWP output)

XXXX TSO FOREGROUND HARDCOPY XXXX 09:50:11 92017 (FIG31)
DSNAME=TSOG04E.UCAP.FIGS

AFT ROTOR-INNER WAKE POINTS.	QUANTITY: 08
NUMBER	R/R
01	0.2000
02	0.3500
03	0.4500
04	0.5500
05	0.6500
06	0.7500
07	0.8500
08	0.9500

Figure 28: AEROEXEC output (GETXMB section 7)

SUBROUTINE: CPMAP.
 INDUCTION CALCULATION POINTS--REAR ROTOR ONTO FWD ROTOR
 STREAMTUBE NO. FLD CALC. POINT

N	RADIUS	STREAMEUBE NO.	FLD CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3500
3	0.4500	2	0.4500
4	0.5500	3	0.5500
5	0.6500	4	0.6500
6	0.7500	4	0.7500
7	0.8500	4	0.8500
8	0.9500	4	0.9500

Figure 29A: AEROEXEC output (CPMAP, front rotor)

SUBROUTINE: CPHAP, DIAMETER RATIO: 1.0000
 WAKE CALCULATION POINTS--FRONT ROTOR ONTO REAR ROTOR
 WAKE CALC. POINT

N	RADIUS	STREAHTUBE NO.	WAKE CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3500
3	0.4500	2	0.4500
4	0.5500	3	0.5500
5	0.6500	4	0.6500
6	0.7500	4	0.7500
7	0.8500	4	0.8500
8	0.9500	4	0.9500

Figure 29B: AEROEXEC output (CPMAP, rear rotor)

```

PROPELLER LIFTING SURFACE PROGRAM IF271      AEROEXEC  EXECCASE      TIME: 1/15/92 UCAP --- NASA      4
*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER HATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP HATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP HATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
LST PROGRAM AND VERSION F271M2.1      03 OCT90
TEMP, DEGF.      56.2
RHO/RHO STD      0.9662
SPEED OF SOUND      1113.4
ADVANCE RATIO      1.4522
FLIGHT HATCH NO.      0.2650
FLIGHT SPD KTS      174.8146
TIP ROT. HATCH      0.5753
TIP SPD. FPS      638.2822
RPM      5956.873
TIP HEL. HATCH      0.6316
START BLENDING      0.9000
DIAMETER      2.0467
NO. BLADES      5
NO. INPT. STA.      22
FREQ. OF UNST.      0.0
NO. NODAL DIA.      0
K-DOWN      0.0250
K-START      0.0100
INPUT STATIONS      0.1000
                        0.7500
                        0.9600
                        0.1746
                        0.1805
                        0.0996
                        0.69.6773
                        48.5225
                        42.3166
                        0.0175
                        0.0322
                        0.1151
                        -0.0020
                        0.0057
                        0.0227
                        0.2149
                        0.0264
                        0.0203
                        0.0324
                        0.2243
                        0.2166
                        -14.4320
                        35.9356
                        30.1285

                        0.3000
                        0.8000
                        0.9700
                        0.1766
                        0.1677
                        0.0925
                        69.6773
                        46.8022
                        42.0334
                        -0.0101
                        0.0175
                        0.0515
                        0.0322
                        0.1188
                        0.0008
                        0.0094
                        0.0236
                        0.0995
                        0.0243
                        0.0204
                        0.0704
                        0.2312
                        0.2128
                        -10.5796
                        36.7154
                        29.7313

                        0.4000
                        0.8250
                        0.9800
                        0.1897
                        0.1601
                        0.0846
                        64.6812
                        46.0226
                        41.7455
                        -0.0237
                        0.0616
                        0.1225
                        -0.0022
                        0.0113
                        0.0245
                        0.0572
                        0.0234
                        0.0201
                        0.1067
                        0.2326
                        0.2086
                        0.2510
                        36.4731
                        29.3917

                        0.5000
                        0.8500
                        0.9900
                        0.2006
                        0.1515
                        0.0760
                        59.6580
                        45.2894
                        41.4581
                        -0.0223
                        0.0719
                        0.1261
                        -0.0027
                        0.0132
                        0.0255
                        0.0440
                        0.0226
                        0.0201
                        0.1474
                        0.2326
                        0.2043
                        13.2020
                        35.7786
                        29.1096

                        0.5500
                        0.8750
                        0.9950
                        0.2026
                        0.1421
                        0.0715
                        57.1517
                        44.5923
                        41.3180
                        -0.0176
                        0.0820
                        0.1279
                        -0.0024
                        0.0152
                        0.0259
                        0.0394
                        0.0219
                        0.0200
                        0.1652
                        0.2314
                        0.2022
                        18.6644
                        34.7056
                        28.9901

                        0.6000
                        0.9000
                        1.0000
                        0.2015
                        0.1319
                        0.0667
                        54.7706
                        43.9170
                        41.1836
                        -0.0098
                        0.0921
                        0.1297
                        -0.0016
                        0.0173
                        0.0264
                        0.0353
                        0.0213
                        0.0200
                        0.1824
                        0.2291
                        0.2022
                        23.8473
                        33.4078
                        28.8795

                        0.6500
                        0.9250
                        0.1971
                        0.1202
                        0.0667
                        52.5466
                        43.2569
                        41.1836
                        0.0010
                        0.1019
                        0.1297
                        0.0000
                        0.0195
                        0.0319
                        0.0208
                        0.0204
                        0.1986
                        0.2257
                        0.2022
                        28.8349
                        31.9988
                        28.8795

                        0.7000
                        0.9500
                        0.1900
                        0.1062
                        0.0667
                        50.4534
                        42.5927
                        41.1836
                        0.0151
                        0.1114
                        0.1297
                        0.0025
                        0.0218
                        0.0289
                        0.0204
                        0.2125
                        0.2199
                        0.2199
                        33.2224
                        30.5831
                        28.8795

```

Figure 30: AEROEXEC output (lifting surface solver)

```

LST CAMBER TABLE          :F271      AEROEXEC EXECASE    TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

*****
UCAP FOR CR-2              INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****

```

CAMBER PLUS TWIST SURFACE ALONG STREAMLINES AS A FUNCTION OF RADIUS (<LOWER CASE R>/RTIP.)

UNBAR TABLE FORMAT.

		TABLE NO.		1. DEGREE		1.	
0.0000E+00	1.0000E-01	2.0000E-01	3.0000E-01	4.0000E-01	5.0000E-01	6.0000E-01	7.0000E-01
1.000E-01	6.90518E+01	6.94046E+01	6.96023E+01	6.97672E+01	6.99399E+01	7.01590E+01	7.04111E+01
3.000E-01	6.90518E+01	6.94046E+01	6.96023E+01	6.97672E+01	6.99399E+01	7.01590E+01	7.04111E+01
4.000E-01	6.29621E+01	6.37112E+01	6.40573E+01	6.43628E+01	6.46935E+01	6.50540E+01	6.54312E+01
5.000E-01	5.70681E+01	5.81944E+01	5.87658E+01	5.91470E+01	5.95075E+01	5.98713E+01	6.02632E+01
5.500E-01	5.42006E+01	5.56424E+01	5.62848E+01	5.66544E+01	5.69875E+01	5.73169E+01	5.76734E+01
6.000E-01	5.14046E+01	5.31170E+01	5.36347E+01	5.4261E+01	5.45747E+01	5.49158E+01	5.52805E+01
6.500E-01	4.87728E+01	5.06346E+01	5.14387E+01	5.18926E+01	5.22966E+01	5.26887E+01	5.31016E+01
7.000E-01	4.62946E+01	4.82883E+01	4.91796E+01	4.96997E+01	5.01608E+01	5.06031E+01	5.10654E+01
7.500E-01	4.40482E+01	4.61915E+01	4.71549E+01	4.77184E+01	4.82143E+01	4.86835E+01	4.91737E+01
8.000E-01	4.21437E+01	4.43751E+01	4.53919E+01	4.59859E+01	4.65032E+01	4.69898E+01	4.74659E+01
8.250E-01	4.13532E+01	4.35025E+01	4.46152E+01	4.52166E+01	4.57416E+01	4.62306E+01	4.67248E+01
8.500E-01	4.06180E+01	4.28622E+01	4.39014E+01	4.45074E+01	4.50302E+01	4.55172E+01	4.60054E+01
8.750E-01	3.99529E+01	4.21975E+01	4.32337E+01	4.38345E+01	4.43516E+01	4.48329E+01	4.53169E+01
9.000E-01	3.93470E+01	4.15640E+01	4.25894E+01	4.31797E+01	4.36858E+01	4.41591E+01	4.46418E+01
9.250E-01	3.87878E+01	4.09582E+01	4.19697E+01	4.25496E+01	4.30439E+01	4.35024E+01	4.39248E+01
9.500E-01	3.82565E+01	4.03032E+01	4.13771E+01	4.19449E+01	4.24864E+01	4.28723E+01	4.33209E+01
9.600E-01	3.80695E+01	4.01565E+01	4.11421E+01	4.17053E+01	4.21979E+01	4.26147E+01	4.30441E+01
9.700E-01	3.78954E+01	3.99279E+01	4.09038E+01	4.14616E+01	4.19278E+01	4.23502E+01	4.27588E+01
9.800E-01	3.76919E+01	3.97009E+01	4.06619E+01	4.12097E+01	4.16662E+01	4.20766E+01	4.24673E+01
9.900E-01	3.74585E+01	3.94759E+01	4.04150E+01	4.09480E+01	4.13943E+01	4.17955E+01	4.21759E+01
9.950E-01	3.73897E+01	3.93503E+01	4.02847E+01	4.08147E+01	4.12562E+01	4.16546E+01	4.20352E+01
1.000E+00	3.72915E+01	3.92323E+01	4.01576E+01	4.06817E+01	4.11193E+01	4.15170E+01	4.19010E+01
9.0000E-01	1.0000E+00						
1.000E-01	7.13028E+01	7.16871E+01					
3.000E-01	7.13028E+01	7.16871E+01					
4.000E-01	6.67261E+01	6.76942E+01					
5.000E-01	6.20474E+01	6.30457E+01					
5.500E-01	5.94657E+01	6.09645E+01					
6.000E-01	5.70960E+01	5.92833E+01					
6.500E-01	5.50825E+01	5.74297E+01					
7.000E-01	5.32787E+01	5.52878E+01					
7.500E-01	5.14970E+01	5.35782E+01					
8.000E-01	4.98001E+01	5.22060E+01					
8.250E-01	4.90107E+01	5.14861E+01					
8.500E-01	4.82742E+01	5.06716E+01					
8.750E-01	4.75660E+01	4.99209E+01					
9.000E-01	4.68876E+01	4.91792E+01					
9.250E-01	4.61887E+01	4.84768E+01					
9.500E-01	4.54279E+01	4.76365E+01					

Figure 31 : AEROEXEC output (1st camber table)

9.600E-01 4.50911E+01 4.72622E+01
9.700E-01 4.47352E+01 4.68776E+01
9.800E-01 4.43698E+01 4.65249E+01
9.900E-01 4.40262E+01 4.61135E+01
9.950E-01 4.38595E+01 4.59638E+01
1.000E+00 4.37141E+01 4.57673E+01

Figure 31 : AEROEXEC output (1st cambr,r table, continued)

SUBROUTINE ANSO: K-INVERSE UNIT NAME: FWD000												
I	HBAR	MU	R/R	THICKNESS		V-AXIAL		V-SWIRL		PI*W/J	CENTER	BODY
				THICK	CAHB	THICK	AXIAL	THICK	SWIRL			
1	1	1	0.200	69.228	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 2.51065
1	2	2	0.200	69.503	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 2.78572
1	3	3	0.200	69.685	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 2.96705
1	4	4	0.200	69.856	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 3.13586
1	5	5	0.200	70.049	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 3.33173
1	6	6	0.200	70.285	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 3.56752
1	7	7	0.200	70.560	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 3.84209
1	8	8	0.200	70.848	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 4.13003
1	9	9	0.200	71.145	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 4.42716
1	10	10	0.200	71.495	0.0000	0.0000	0.0000	0.0000	0.0000	0.4303	0.0000	WMU: 4.77721
2	1	11	0.350	66.282	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 13.26350
2	2	12	0.350	66.694	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 13.67521
2	3	13	0.350	66.947	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 13.92878
2	4	14	0.350	67.191	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 14.17270
2	5	15	0.350	67.462	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 14.44344
2	6	16	0.350	67.764	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 14.74519
2	7	17	0.350	68.102	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 15.08334
2	8	18	0.350	68.430	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 15.41127
2	9	19	0.350	68.796	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 15.77710
2	10	20	0.350	69.353	0.0000	0.0000	0.0000	0.0000	0.0000	0.7531	0.0000	WMU: 16.33392
3	1	21	0.450	60.484	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 14.55850
3	2	22	0.450	61.182	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 15.25671
3	3	23	0.450	61.583	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 15.65774
3	4	24	0.450	61.928	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 16.00268
3	5	25	0.450	62.282	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 16.35656
3	6	26	0.450	62.655	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 16.72943
3	7	27	0.450	63.059	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 17.13312
3	8	28	0.450	63.492	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 17.56637
3	9	29	0.450	64.050	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 18.12476
3	10	30	0.450	64.678	0.0000	0.0000	0.0000	0.0000	0.0000	0.9682	0.0000	WMU: 18.95291
4	1	31	0.550	54.922	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 14.72212
4	2	32	0.550	55.964	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 15.76423
4	3	33	0.550	56.470	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 16.27025
4	4	34	0.550	56.821	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 16.62158
4	5	35	0.550	57.152	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 16.95279
4	6	36	0.550	57.495	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 17.29576
4	7	37	0.550	57.874	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 17.67469
4	8	38	0.550	58.311	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 18.11157
4	9	39	0.550	59.006	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 18.80706
4	10	40	0.550	60.215	0.0000	0.0000	0.0000	0.0000	0.0000	1.1834	0.0000	WMU: 20.01570
5	1	41	0.650	49.704	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 14.13747
5	2	42	0.650	51.037	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 15.47043
5	3	43	0.650	51.666	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 16.09940
5	4	44	0.650	52.095	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 16.52837
5	5	45	0.650	52.493	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 16.92644
5	6	46	0.650	52.895	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 17.32895
5	7	47	0.650	53.344	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 17.77770
5	8	48	0.650	53.757	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 18.19100
5	9	49	0.650	54.505	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 18.93913
5	10	50	0.650	56.256	0.0000	0.0000	0.0000	0.0000	0.0000	1.3986	0.0000	WMU: 20.68987
6	1	51	0.750	45.120	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 13.33342
6	2	52	0.750	46.673	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 14.88673
6	3	53	0.750	47.437	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 15.65019
6	4	54	0.750	47.966	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 16.17991
6	5	55	0.750	48.450	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 16.66337
6	6	56	0.750	48.930	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 17.18305
6	7	57	0.750	49.440	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 17.65377
6	8	58	0.750	49.993	0.0000	0.0000	0.0000	0.0000	0.0000	1.6137	0.0000	WMU: 18.20695

6 9	59	0.750	50.889	0.0000	0.0000	0.0000	1.6137	0.0000	WHU:	19.10207
6 10	60	0.750	52.538	0.0000	0.0000	0.0000	1.6137	0.0000	WHU:	20.75117
7 1	61	0.850	41.736	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	13.06657
7 2	62	0.850	43.382	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	14.71228
7 3	63	0.850	44.204	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	15.53887
7 4	64	0.850	44.769	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	16.09927
7 5	65	0.850	45.274	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	16.60419
7 6	66	0.850	45.761	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	17.09177
7 7	67	0.850	46.274	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	17.60468
7 8	68	0.850	46.776	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	18.10675
7 9	69	0.850	47.642	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	18.97234
7 10	70	0.850	49.473	0.0000	0.0000	0.0000	1.8289	0.0000	WHU:	20.80339
8 1	71	0.950	39.320	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	13.25036
8 2	72	0.950	40.880	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	14.81067
8 3	73	0.950	41.661	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	15.59152
8 4	74	0.950	42.186	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	16.11615
8 5	75	0.950	42.649	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	16.57985
8 6	76	0.950	43.097	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	17.02709
8 7	77	0.950	43.573	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	17.50361
8 8	78	0.950	44.043	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	17.97372
8 9	79	0.950	44.844	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	18.77498
8 10	80	0.950	46.532	0.0000	0.0000	0.0000	2.0440	0.0000	WHU:	20.46268

COEFFICIENT OF SOUND POWER = 0.000005 - SOUND POWER/ (RHO* RPS*MM3* DIA*MM5)

Figure 32 : AEROEXEC output (ANS0, continued plus coefficient of sound power)

```

LSTDY: PERFORMANCE SUMMARY      AEROEXEC  EXECCASE      TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA  4
*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
ITERATION NUMBER      1.
PERFORMANCE WITHOUT VORTEX LIFT
CP--FORWARD ROTOR      0.9202
CT--FORWARD ROTOR      0.4716
PERFORMANCE WITH VORTEX LIFT
CP--FORWARD ROTOR      1.6138
CT--FORWARD ROTOR      0.5772
*****

```

Figure 33: AEROEXEC output (Individual rotor performance summary)

```

VORTEX CALC. RESULTS (FWD) : VTOUT      AEROEXEC  EXECCASE    TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA    4
*****
UCAP FOR CR-2      INPUT -- R252INPT.DAT
HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
***** FIRST ATTEMPT AT POWER MATCH *****
FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP HATCH = 48.87
REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP HATCH = 48.54
FRONT & REAR BLADES ASSUMED IDENTICAL
*****
RUNNING FWD ROW : UAAP CALCULATION VERSION 4 : PERFORMANCE CALCULATION ON THE BLADE VERSION 0
*****

```

***** OPERATING CONDITIONS *****

FLIGHT HATCH #	TIP ROT. HATCH #	ADVANCE RATIO	TEMP. DEG F	DENSITY RATIO
0.2650	0.5702	1.4601	56.18	0.9662

# RADIAL STATIONS	# CHORD- WISE STATIONS	# SPAN- WISE MODES	MODOPT	NBOPT
22	10	8	4	2

Figure 34: AEROEXEC output (vortex calculations: operating conditions)

BLADE GEOMETRY :		THETA 3/4	#	BLADES	DIAMETER	SPINNER CUTOFF								
		48.87	6.	2.047	0.2450									
RADIAL STATION	CHORD/ DIAH	THICK/ CHORD	MID-CHORD XMC	MID-CHORD YMC	COORDINATES ZMC	FACE ALINE	MID-CHORD ALINE	SWEEP	L. E. SWEEP	L. E. A.O.A.	ALPHA 3-D	INDUCED ANGLE	ADVANCE ANGLE	BLADE ANGLE
0.1000	0.1747	0.2149	0.2208	-0.0001	0.0017	-0.0019	0.0175	-14.42	-15.42	-9.59	-7.85	-17.23	77.86	70.00
0.3000	0.1747	0.0995	0.2998	-0.0122	-0.0162	0.0007	-0.0101	-10.59	-17.96	11.10	12.85	9.91	57.16	70.00
0.4000	0.1897	0.0572	0.3991	-0.0274	-0.0368	-0.0022	-0.0237	0.22	-14.18	12.52	15.72	11.47	49.28	65.00
0.5000	0.2006	0.0440	0.4992	-0.0291	-0.0346	-0.0028	-0.0224	13.18	-0.29	13.38	17.07	12.76	42.91	59.98
0.5500	0.2026	0.0394	0.5495	-0.0236	-0.0265	-0.0025	-0.0176	12.64	13.73	13.37	17.28	12.91	40.20	57.48
0.6000	0.2015	0.0353	0.5998	-0.0135	-0.0145	-0.0016	-0.0098	23.84	23.14	13.18	17.33	12.65	37.76	55.10
0.6500	0.1971	0.0319	0.6500	0.0016	0.0012	0.0000	0.0010	28.84	31.45	12.86	17.31	11.99	35.57	52.87
0.7000	0.1900	0.0289	0.6996	0.0223	0.0209	0.0025	0.0151	33.23	38.27	12.48	17.20	11.01	33.58	50.78
0.7500	0.1805	0.0264	0.7484	0.0485	0.0458	0.0056	0.0322	35.96	43.56	12.10	17.06	9.77	31.79	48.85
0.8000	0.1678	0.0243	0.7961	0.0793	0.0683	0.0096	0.0515	36.75	46.57	11.91	16.97	8.28	30.15	47.12
0.8250	0.1601	0.0234	0.8194	0.0959	0.0805	0.0115	0.0616	36.51	48.70	11.89	16.95	7.35	29.39	46.34
0.8500	0.1516	0.0226	0.8425	0.1128	0.0925	0.0134	0.0718	35.80	49.63	11.91	16.94	6.20	28.67	45.61
0.8750	0.1422	0.0219	0.8653	0.1299	0.1043	0.0155	0.0820	34.74	50.25	11.96	16.94	4.70	27.98	44.91
0.9000	0.1319	0.0213	0.8880	0.1467	0.1158	0.0176	0.0921	33.44	50.93	12.02	16.92	2.67	27.31	44.24
0.9250	0.1202	0.0208	0.9105	0.1633	0.1270	0.0199	0.1018	32.94	52.18	12.10	16.90	-0.09	26.68	43.58
0.9500	0.1061	0.0204	0.9329	0.1795	0.1378	0.0222	0.1114	30.65	53.41	12.19	16.84	-3.73	26.07	42.91
0.9600	0.0996	0.0203	0.9418	0.1858	0.1420	0.0231	0.1151	30.26	55.02	12.23	16.80	-5.35	25.83	42.64
0.9700	0.0924	0.0202	0.9508	0.1922	0.1461	0.0240	0.1188	29.89	56.08	12.26	16.75	-6.84	25.60	42.35
0.9800	0.0865	0.0201	0.9597	0.1984	0.1502	0.0250	0.1224	29.53	57.19	12.30	16.69	-7.70	25.37	42.06
0.9900	0.0759	0.0201	0.9686	0.2047	0.1542	0.0259	0.1261	29.19	58.05	12.35	16.63	-6.33	25.15	41.78
0.9950	0.0713	0.0200	0.9731	0.2078	0.1562	0.0264	0.1279	29.03	58.96	12.31	16.60	-3.04	25.04	41.64
1.0000	0.0665	0.0200	0.9775	0.2109	0.1582	0.0269	0.1297	28.88	59.28	12.37	16.57	0.00	24.93	41.50

Figure 35: AEROEXEC output (vortex calculations: elemental data)

COEFFICIENTS FROM POTENTIAL CALC.:									
RADIAL STATION	DRAG CDLST	DRAG CDROT	LIFT CLIST	LIFT CLROT	L. E. K, MAG.	L. E. THRUST	RELATIVE MACH #	DESIGN CL	
0.1000	0.0072	-0.0499	0.1696	0.1611	0.2393	0.0225	0.2711	0.0324	
0.3000	0.0367	0.0684	0.4060	0.3913	0.1885	0.0140	0.3154	0.0704	
0.4000	0.0512	0.1008	0.5235	0.4964	0.2564	0.0258	0.3496	0.1067	
0.5000	0.0473	0.1224	0.5768	0.5406	0.2696	0.0285	0.3892	0.1474	
0.5500	0.0414	0.1266	0.5907	0.5525	0.2758	0.0299	0.4106	0.1652	
0.6000	0.0389	0.1263	0.6012	0.5628	0.2902	0.0331	0.4327	0.1824	
0.6500	0.0428	0.1217	0.6101	0.5728	0.3140	0.0387	0.4556	0.1986	
0.7000	0.0479	0.1132	0.6170	0.5820	0.3449	0.0467	0.4791	0.2125	
0.7500	0.0514	0.1018	0.6234	0.5914	0.3809	0.0570	0.5031	0.2243	
0.8000	0.0522	0.0880	0.6334	0.6048	0.4254	0.0711	0.5275	0.2312	
0.8250	0.0518	0.0792	0.6399	0.6134	0.4533	0.0807	0.5599	0.2326	
0.8500	0.0506	0.0677	0.6465	0.6226	0.4869	0.0931	0.5524	0.2326	
0.8750	0.0478	0.0518	0.6507	0.6306	0.5276	0.1093	0.5649	0.2314	
0.9000	0.0420	0.0296	0.6483	0.6336	0.5759	0.1302	0.5775	0.2291	
0.9250	0.0303	-0.0010	0.6364	0.6271	0.6312	0.1564	0.5902	0.2257	
0.9500	0.0229	-0.0392	0.5990	0.6014	0.6861	0.1849	0.6030	0.2199	
0.9600	0.0194	-0.0543	0.5736	0.5800	0.7013	0.1932	0.6081	0.2166	
0.9700	0.0143	-0.0655	0.5362	0.5459	0.7038	0.1945	0.6133	0.2128	
0.9800	0.0098	-0.0660	0.4774	0.4882	0.6770	0.1800	0.6184	0.2086	
0.9900	0.0052	-0.0421	0.3732	0.3800	0.5757	0.1301	0.6236	0.2043	
0.9950	0.0043	-0.0149	0.2793	0.2809	0.4507	0.0798	0.6262	0.2022	
1.0000	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.6288	0.2000	

Figure 36: AEROEXEC output (vortex calculations: coefficients from potential calculation)

PERFORMANCE CALCULATIONS - LIFT COEFFICIENTS
 ***** NOTE THAT VORTEX LIFT COMPONENTS ARE NOT PRESENTED AS PERPENDICULAR TO THE LOCAL ADVANCE ANGLE *****

RADIAL STATION	POT. LIFT	L. E. VORTEX	TIP VORTEX	AUGMENTED VORTEX	TOTAL LIFT
0.1000	0.1611	0.0000	0.0000	0.0000	0.1611
0.3000	0.3913	0.0000	0.0000	0.0000	0.3913
0.4000	0.4964	0.0000	0.0000	0.0000	0.4964
0.5000	0.5406	0.0000	0.0000	0.0000	0.5406
0.5500	0.5525	0.0307	0.0000	0.0000	0.5755
0.6000	0.5628	0.0360	0.0000	0.0000	0.5903
0.6500	0.5728	0.0454	0.0000	0.0000	0.6004
0.7000	0.5820	0.0595	0.0000	0.0000	0.6299
0.7500	0.5914	0.0706	0.0000	0.0000	0.6563
0.8000	0.6048	0.1034	0.0000	0.0000	0.6912
0.8250	0.6134	0.1222	0.0000	0.0000	0.7164
0.8500	0.6226	0.1437	0.0000	0.0000	0.7440
0.8750	0.6306	0.1710	0.0000	0.0000	0.7752
0.9000	0.6336	0.2066	0.0000	0.0000	0.8066
0.9250	0.6271	0.2551	0.0000	0.0000	0.8437
0.9500	0.6014	0.3102	0.0000	0.6492	1.4869
0.9600	0.5000	0.3369	0.5751	1.0805	2.4609
0.9700	0.5459	0.3486	0.9143	1.2978	2.9855
0.9800	0.4802	0.3321	0.9829	1.2401	2.9037
0.9900	0.3800	0.2459	0.7174	0.8486	2.0929
0.9950	0.2809	0.1547	0.4268	0.4927	1.2955
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

INCREMENTAL LIFTS AND DRAGS

RADIAL STATION	POT. LIFT	POT. LE	VORTEX SE	POT. AUGVORT	TOTAL LIFT	POT. DRAG	POT. LE	VORTEX SE	POT. AUGVORT	TOTAL DRAG
0.1000	0.1611	0.1611	0.0000	0.0000	0.1611	-0.0499	-0.0499	-0.0499	-0.0499	-0.0427
0.3000	0.3913	0.3913	0.0000	0.0000	0.3913	0.0684	0.0684	0.0684	0.0684	0.1050
0.4000	0.4964	0.4964	0.0000	0.0000	0.4964	0.1008	0.1008	0.1008	0.1008	0.1520
0.5000	0.5406	0.5406	0.0000	0.0000	0.5406	0.1224	0.1224	0.1224	0.1224	0.1697
0.5500	0.5525	0.5755	0.0307	0.0000	0.5755	0.1266	0.1266	0.1266	0.1266	0.2043
0.6000	0.5628	0.5903	0.0360	0.0000	0.5903	0.1263	0.1263	0.1263	0.1263	0.2056
0.6500	0.5728	0.6004	0.0454	0.0000	0.6004	0.1217	0.1217	0.1217	0.1217	0.2123
0.7000	0.5820	0.6299	0.0595	0.0000	0.6299	0.1132	0.1132	0.1132	0.1132	0.2196
0.7500	0.5914	0.6563	0.0706	0.0000	0.6563	0.1018	0.1018	0.1018	0.1018	0.2254
0.8000	0.6048	0.6912	0.1034	0.0000	0.6912	0.0880	0.0880	0.0880	0.0880	0.2310
0.8250	0.6134	0.7164	0.1222	0.0000	0.7164	0.0792	0.0792	0.0792	0.0792	0.2351
0.8500	0.6226	0.7440	0.1437	0.0000	0.7440	0.0677	0.0677	0.0677	0.0677	0.2390
0.8750	0.6306	0.7752	0.1710	0.0000	0.7752	0.0518	0.0518	0.0518	0.0518	0.2420
0.9000	0.6336	0.8066	0.2066	0.0000	0.8066	0.0296	0.0296	0.0296	0.0296	0.2420
0.9250	0.6271	0.8437	0.2551	0.0000	0.8437	-0.0010	0.2055	-0.0010	-0.0010	0.2358
0.9500	0.6014	0.8869	0.3102	0.6492	1.4869	-0.0392	0.2070	-0.0392	0.1489	0.4180
0.9600	0.5000	0.9855	0.3369	1.0805	2.4609	-0.0543	0.2058	0.1119	0.2603	0.7061
0.9700	0.5459	0.9837	0.3486	1.2978	2.9855	-0.0655	0.1986	0.1986	0.3086	0.6505
0.9800	0.4802	0.9037	0.3321	1.2401	2.9037	-0.0660	0.1806	0.2163	0.2902	0.6289
0.9900	0.3800	0.8037	0.2459	0.7174	2.0929	-0.0421	0.1376	0.1632	0.2807	0.5909
0.9950	0.2809	0.7531	0.1547	0.4268	1.2955	-0.0149	0.0960	0.1068	0.1258	0.3627
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0054

Figure 37: AEROEXEC output (vortex calculations: lift coefficients and incremental lifts and drags)

PERFORMANCE SUMMARY

ELEMENTAL PERFORMANCE

RADIAL STATION	POTENTIAL		POT+LEAD EDGE		EDGE VORTEX		POT+SIDE		EDGE VORTEX		POT+AUCTIONED		VORTEX		TOTAL	
	DCP/DX	DETA/DX	DCP/DX	DETA/DX	DCP/DX	DETA/DX	DCP/DX	DETA/DX	DCP/DX	DETA/DX	DCP/DX	DETA/DX	DCP/DX	DETA/DX	DCP/DX	DETA/DX
0.1000	0.0270	0.0483	0.0270	0.0483	0.0270	0.0483	0.0270	0.0483	0.0270	0.0483	0.0270	0.0483	0.0270	0.0483	0.0273	0.0442
0.3000	0.2720	0.1225	0.2720	0.1225	0.2720	0.1225	0.2720	0.1225	0.2720	0.1225	0.2720	0.1225	0.2720	0.1225	0.2877	0.0981
0.4000	0.5864	0.2613	0.5864	0.2613	0.5864	0.2613	0.5864	0.2613	0.5864	0.2613	0.5864	0.2613	0.5864	0.2613	0.6307	0.2203
0.5000	0.9949	0.4326	0.9949	0.4326	0.9949	0.4326	0.9949	0.4326	0.9949	0.4326	0.9949	0.4326	0.9949	0.4326	1.0702	0.3881
0.5500	1.2182	0.5292	1.3324	0.5202	1.3324	0.5202	1.2182	0.5292	1.3324	0.5202	1.2182	0.5292	1.3324	0.5202	1.4174	0.4786
0.6000	1.4593	0.6315	1.5973	0.6263	1.5973	0.6263	1.4593	0.6315	1.5973	0.6263	1.4593	0.6315	1.5973	0.6263	1.6968	0.5854
0.6500	1.6937	0.7361	1.8707	0.7382	1.8707	0.7382	1.6937	0.7361	1.8707	0.7382	1.6937	0.7361	1.8707	0.7382	2.0030	0.6919
0.7000	1.8178	0.8386	2.1465	0.8537	2.1465	0.8537	1.8178	0.8386	2.1465	0.8537	1.8178	0.8386	2.1465	0.8537	2.3289	0.8011
0.7500	1.9510	0.9342	2.4195	0.9699	2.4195	0.9699	1.9510	0.9342	2.4195	0.9699	1.9510	0.9342	2.4195	0.9699	2.6335	0.9136
0.8000	2.0301	1.0180	2.6022	1.0799	2.6022	1.0799	2.0301	1.0180	2.6022	1.0799	2.0301	1.0180	2.6022	1.0799	2.9232	1.0242
0.8250	2.0386	1.0534	2.8169	1.1354	2.8169	1.1354	2.0386	1.0534	2.8169	1.1354	2.0386	1.0534	2.8169	1.1354	3.0656	1.0814
0.8500	2.0138	1.0021	2.9371	1.1844	2.9371	1.1844	2.0138	1.0021	2.9371	1.1844	2.0138	1.0021	2.9371	1.1844	3.1865	1.1333
0.8750	1.9399	1.1003	3.0391	1.2261	3.0391	1.2261	1.9399	1.1003	3.0391	1.2261	1.9399	1.1003	3.0391	1.2261	3.2789	1.1798
0.9000	1.7954	1.1006	3.1079	1.2554	3.1079	1.2554	1.7954	1.1006	3.1079	1.2554	1.7954	1.1006	3.1079	1.2554	3.3192	1.2169
0.9250	1.5554	1.0695	3.1167	1.2618	3.1167	1.2618	1.5554	1.0695	3.1167	1.2618	1.5554	1.0695	3.1167	1.2618	3.2670	1.2359
0.9500	1.2013	0.9797	2.9701	1.2065	2.9701	1.2065	1.2013	0.9797	2.9701	1.2065	1.2013	0.9797	2.9701	1.2065	3.5964	2.0243
0.9600	1.0310	0.9151	2.9507	1.1603	2.9507	1.1603	1.0310	0.9151	2.9507	1.1603	1.0310	0.9151	2.9507	1.1603	3.6380	3.1986
0.9700	0.8525	0.8237	2.6245	1.0703	2.6245	1.0703	0.8525	0.8237	2.6245	1.0703	0.8525	0.8237	2.6245	1.0703	3.6726	3.6473
0.9800	0.6779	0.6909	2.2434	0.9160	2.2434	0.9160	0.6779	0.6909	2.2434	0.9160	0.6779	0.6909	2.2434	0.9160	3.0328	3.3591
0.9900	0.5150	0.4866	1.5734	0.6424	1.5734	0.6424	0.5150	0.4866	1.5734	0.6424	0.5150	0.4866	1.5734	0.6424	5.9555	2.2095
0.9950	0.4195	0.3322	1.0456	0.4272	1.0456	0.4272	0.4195	0.3322	1.0456	0.4272	0.4195	0.3322	1.0456	0.4272	3.4909	1.2993
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0183	-0.0027
																-0.2158

Figure 38: AEROEXEC output (vortex calculations: performance summary)

!!

SUBROUTINE: INTFRS. GEOMETRY DATA
 NUMBER OF RADIAL STATIONS: 22
 INTEGRATION MESH SIZE DENOMINATOR: 10

INDEX	R/RTP	CHD/D	ZMC	DCPDZ	DCTDZ	INDEX	R/RTP	CHD/D	ZMC	DCPDZ	DCTDZ
1	0.100	0.175	+0.002	+0.044	+0.027	1	+2	+0.300	+0.175	-0.016	+0.288
3	0.400	0.190	-0.039	+0.220	+0.631	1	+4	+0.500	+0.201	-0.035	+0.388
5	0.550	0.203	-0.026	+0.479	+1.417	1	+6	+0.600	+0.201	-0.015	+0.585
7	0.650	0.197	+0.001	+0.692	+2.003	1	+8	+0.700	+0.190	+0.021	+0.801
9	0.750	0.181	+0.044	+0.914	+2.634	1	+10	+0.800	+0.168	+0.068	+2.321
11	0.825	0.160	+0.080	+1.061	+3.066	1	+12	+0.850	+0.152	+1.024	+2.923
13	0.875	0.142	+0.104	+1.180	+3.279	1	+14	+0.900	+0.132	+1.133	+3.187
15	0.925	0.120	+0.127	+1.236	+3.267	1	+16	+0.950	+0.106	+1.217	+3.319
17	0.960	0.100	+0.142	+3.199	+8.638	1	+18	+0.970	+0.092	+2.024	+5.396
19	0.980	0.085	+0.150	+3.339	+9.033	1	+20	+0.990	+0.076	+0.146	+3.647
21	0.995	0.071	+0.156	+1.299	+3.491	1	+22	+1.000	+0.067	+0.154	+5.955
										-0.003	+0.018

ROTOR: FWD

ADVANCE RATIO: 1.460

MACH NUMBER: 0.265

NUMBER OF OUTPUT RADII: 8 USED OF 10 ALLOWED

NUMBER OF AXIAL POINTS: 10 PER OUTPUT RADIUS.

INDEX RADIUS AXIAL LOCATION VX-POT. VX-2DARY

INDEX	RADIUS	AXIAL LOCATION	VX-POT.	VX-2DARY
1	0.200			
1		0.373	0.028	-0.005
2		0.406	0.028	-0.005
3		0.438	0.028	-0.005
4		0.471	0.028	-0.005
5		0.504	0.028	-0.005
6		0.537	0.028	-0.005
7		0.569	0.028	-0.005
8		0.602	0.028	-0.005
9		0.635	0.028	-0.005
10		0.668	0.028	-0.005
2	0.350			
1		0.335	0.050	-0.010
2		0.369	0.050	-0.010
3		0.402	0.050	-0.010
4		0.436	0.050	-0.010
5		0.469	0.050	-0.010
6		0.503	0.050	-0.010
7		0.537	0.050	-0.010
8		0.570	0.050	-0.010
9		0.604	0.050	-0.010
10		0.637	0.050	-0.010
3	0.450			
1		0.322	0.080	-0.012
2		0.357	0.080	-0.012
3		0.391	0.080	-0.012
4		0.426	0.080	-0.012
5		0.460	0.080	-0.012
6		0.495	0.080	-0.012
7		0.529	0.080	-0.012
8		0.564	0.080	-0.012
9		0.598	0.080	-0.012
10		0.633	0.080	-0.012
4	0.550			
1		0.334	0.106	-0.010
2		0.368	0.106	-0.010

Figure 40 : AEROEXEC output (steady interference velocity field calculation)

INDEX	RADIUS	CHORD/D	ZMC	DC10Z	DCPDZ	HBAR	HU	X/PCA	X/C/2	RX	V/AXIAL	V/SWIRL
1	0.200	0.1747	-0.0073	+0.071	+0.157	1	01	+0.373	+2.369	+1.000	-0.168	+0.366
2						2	02	+0.406	+2.573	+1.000	-0.154	+0.366
3						3	03	+0.438	+2.777	+1.000	-0.141	+0.366
4						4	04	+0.471	+2.981	+1.000	-0.130	+0.366
5						5	05	+0.504	+3.185	+1.000	-0.120	+0.366
6						6	06	+0.537	+3.390	+1.000	-0.110	+0.366
7												
8												
9												
10												
5	0.650											
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
6	0.750											
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
7	0.850											
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
8	0.950											
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Figure 40 : AEROEXEC output (steady interference velocity field calculation, continued)

2	0.350	0.1822	-0.0275	+0.159	+0.459	7	07	+0.569	+3.594	+1.000	-0.101	+0.366
						8	08	+0.602	+3.798	+1.000	-0.093	+0.366
						9	09	+0.635	+4.002	+1.000	-0.086	+0.366
						10	10	+0.668	+4.206	+1.000	-0.078	+0.366
3	0.450	0.1951	-0.0367	+0.304	+0.850	1	11	+0.335	+2.492	+1.000	-0.105	+0.343
						2	12	+0.368	+2.722	+1.000	-0.094	+0.343
						3	13	+0.402	+2.953	+1.000	-0.083	+0.343
						4	14	+0.436	+3.184	+1.000	-0.074	+0.343
						5	15	+0.469	+3.415	+1.000	-0.065	+0.343
						6	16	+0.503	+3.645	+1.000	-0.056	+0.343
						7	17	+0.537	+3.876	+1.000	-0.049	+0.343
						8	18	+0.570	+4.107	+1.000	-0.041	+0.343
						9	19	+0.604	+4.337	+1.000	-0.034	+0.343
						10	20	+0.637	+4.568	+1.000	-0.027	+0.343
						1	21	+0.322	+2.560	+1.000	-0.013	+0.374
						2	22	+0.357	+2.807	+1.000	-0.004	+0.374
4	0.550	0.2026	-0.0265	+0.479	+1.417	3	23	+0.391	+3.053	+1.000	+0.004	+0.374
						4	24	+0.426	+3.299	+1.000	+0.012	+0.374
						5	25	+0.460	+3.545	+1.000	+0.020	+0.374
						6	26	+0.495	+3.791	+1.000	+0.027	+0.374
						7	27	+0.529	+4.037	+1.000	+0.034	+0.374
						8	28	+0.564	+4.284	+1.000	+0.040	+0.374
						9	29	+0.598	+4.530	+1.000	+0.047	+0.374
						10	30	+0.633	+4.776	+1.000	+0.053	+0.374
						1	31	+0.334	+2.760	+1.000	+0.072	+0.406
						2	32	+0.368	+3.020	+1.000	+0.079	+0.406
						3	33	+0.403	+3.281	+1.000	+0.085	+0.406
						4	34	+0.437	+3.541	+1.000	+0.092	+0.406
5	0.650	0.1971	0.0012	+0.692	+2.003	5	35	+0.471	+3.801	+1.000	+0.098	+0.406
						6	36	+0.505	+4.062	+1.000	+0.104	+0.406
						7	37	+0.539	+4.322	+1.000	+0.110	+0.406
						8	38	+0.573	+4.583	+1.000	+0.116	+0.406
						9	39	+0.607	+4.843	+1.000	+0.121	+0.406
						10	40	+0.641	+5.103	+1.000	+0.126	+0.406
						1	41	+0.374	+3.256	+1.000	+0.157	+0.410
						2	42	+0.406	+3.529	+1.000	+0.162	+0.410
						3	43	+0.437	+3.802	+1.000	+0.168	+0.410
						4	44	+0.468	+4.075	+1.000	+0.173	+0.410
						5	45	+0.500	+4.348	+1.000	+0.177	+0.410
						6	46	+0.531	+4.621	+1.000	+0.182	+0.410
6	0.750	0.1805	0.0438	+0.914	+2.634	7	47	+0.562	+4.894	+1.000	+0.187	+0.410
						8	48	+0.593	+5.167	+1.000	+0.191	+0.410
						9	49	+0.625	+5.440	+1.000	+0.195	+0.410
						10	50	+0.656	+5.713	+1.000	+0.199	+0.410
						1	51	+0.436	+4.123	+1.000	+0.230	+0.403
						2	52	+0.463	+4.407	+1.000	+0.234	+0.403
						3	53	+0.490	+4.692	+1.000	+0.238	+0.403
						4	54	+0.517	+4.976	+1.000	+0.241	+0.403
						5	55	+0.544	+5.261	+1.000	+0.245	+0.403
						6	56	+0.571	+5.545	+1.000	+0.248	+0.403
						7	57	+0.598	+5.829	+1.000	+0.252	+0.403
						8	58	+0.625	+6.114	+1.000	+0.255	+0.403
7	0.850	0.1516	0.0925	+1.133	+3.187	9	59	+0.652	+6.398	+1.000	+0.258	+0.403
						10	60	+0.679	+6.683	+1.000	+0.261	+0.403

Figure 40 AEROEXEC output (steady interference velocity field calculation, continued)

8	0.950	0.1061	0.1378	+2.024	+5.396	1	61	+0.549	+5.726	+1.000	+0.291	+0.378
						2	62	+0.530	+6.022	+1.000	+0.295	+0.378
						3	63	+0.552	+6.318	+1.000	+0.295	+0.378
						4	64	+0.573	+6.614	+1.000	+0.298	+0.378
						5	65	+0.595	+6.911	+1.000	+0.300	+0.378
						6	66	+0.617	+7.207	+1.000	+0.302	+0.378
						7	67	+0.638	+7.503	+1.000	+0.304	+0.378
						8	68	+0.660	+7.799	+1.000	+0.306	+0.378
						9	69	+0.681	+8.095	+1.000	+0.308	+0.378
						10	70	+0.703	+8.391	+1.000	+0.309	+0.378
						1	71	+0.586	+9.610	+1.000	+0.551	+0.511
						2	72	+0.600	+9.918	+1.000	+0.552	+0.511
						3	73	+0.615	+10.226	+1.000	+0.553	+0.511
						4	74	+0.629	+10.534	+1.000	+0.554	+0.511
						5	75	+0.643	+10.842	+1.000	+0.555	+0.511
						6	76	+0.658	+11.150	+1.000	+0.556	+0.511
						7	77	+0.672	+11.458	+1.000	+0.557	+0.511
						8	78	+0.687	+11.766	+1.000	+0.558	+0.511
						9	79	+0.701	+12.075	+1.000	+0.559	+0.511
						10	80	+0.715	+12.383	+1.000	+0.560	+0.511

Figure 40 : AEROEXEC output (steady interference velocity field calculation, continued)

PASS 1 OF 21; TOL: 1.000E-02 AEROEXEC EXECASE YIPF: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DAT

HX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS

6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT

***** FIRST ATTEMPT AT POWER MATCH *****

FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87

REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54

FRONT & REAR BLADES ASSUMED IDENTICAL

RATIOS (REAR ROTOR DIVIDED BY FORWARD ROTOR)

DIAMETER RATIO: 1.0000

ANGULAR VELOCITY: 1.0054

TIP SPEED: 1.0054

ROTOR-ROTOR SPACING: 0.2570 (DIVIDED BY FRONT ROTOR DIAMETER.)

COEFFICIENT	FORWARD	AFT	TOTAL
-------------	---------	-----	-------

PERFORMANCE SUMMARY WITHOUT VORTEX LOADING.

ADVANCE RATIO	1.46	1.45	
POWER	0.920	0.677	1.01
THRUST	0.472	0.468	0.945
TORQUE	0.146	0.140	0.286
EFFICIENCY	0.748	0.776	0.762
ROLLING MOMENT			0.540E-02

RATIO	FORWARD/TOTAL	AFT/TOTAL	AFT/FORWARD
TIP SPEED			1.01
DIAMETER			1.00
ANGULAR SPEED			1.01
AREA	0.500	0.500	1.00
POWER	0.508	0.492	0.968
THRUST	0.499	0.501	1.01
TORQUE	0.509	0.491	0.963

Figure 41 : AEROEXEC output (PRTPRF: counter-rotation performance summary)

PERFORMANCE SUMMARY INCLUDING VORTEX LOADING.

ADVANCE RATIO	1.46	1.45	
POWER	1.61	1.46	3.09
THRUST	0.577	0.511	1.09
TORQUE	0.257	0.232	0.491
EFFICIENCY	0.522	0.510	0.516
ROLLING MOMENT			0.226E-01

RATIO	FORWARD/TOTAL	AFT/TOTAL	AFT/FORWARD
TIP SPEED			1.01
DIAHETER			1.00
ANGULAR SPEED			1.01
AREA	0.500	0.500	1.00
POWER	0.522	0.478	0.917
THRUST	0.528	0.472	0.900
TORQUE	0.523	0.477	0.912

Figure 41 : AEROEXEC output (PRTPRF: counter-rotation performance summary, continued)

SBR: ADJUST. FORWARD ROTOR DATA AEROEXEC EXECCASE TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DAT

MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS

6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT

***** FIRST ATTEMPT AT POWER MATCH *****

FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87

REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54

FRONT & REAR BLADES ASSUMED IDENTICAL

SUBROUTINE ADJUST

NUMBER OF SPANWISE HOLES: 8

NUMBER OF CHORDWISE PANELS 10

STATION V-AXIAL

1	0.200	1.2628	M	HU	POTENTIAL 2D-ARY	OTHER ROTOR
1	1	1	1	1	0.0284	0.1922
	2	2	2	2	0.0284	0.2007
	3	3	3	3	0.0284	0.2098
	4	4	4	4	0.0284	0.2196
	5	5	5	5	0.0284	0.2301
	6	6	6	6	0.0284	0.2415
	7	7	7	7	0.0284	0.2540
	8	8	8	8	0.0284	0.2677
	9	9	9	9	0.0284	0.2829
	10	10	10	10	0.0284	0.2999
2	0.350	1.2354	M	HU	POTENTIAL 2D-ARY	OTHER ROTOR
	1	1	11	11	0.0498	0.1559
	2	2	12	12	0.0498	0.1630
	3	3	13	13	0.0498	0.1705
	4	4	14	14	0.0498	0.1786
	5	5	15	15	0.0498	0.1873
	6	6	16	16	0.0498	0.1968
	7	7	17	17	0.0498	0.2070
	8	8	18	18	0.0498	0.2183
	9	9	19	19	0.0498	0.2306
	10	10	20	20	0.0498	0.2442
3	0.450	1.2406	M	HU	POTENTIAL 2D-ARY	OTHER ROTOR
	1	1	21	21	0.0803	0.1380
	2	2	22	22	0.0803	0.1442
	3	3	23	23	0.0803	0.1509
	4	4	24	24	0.0803	0.1580
	5	5	25	25	0.0803	0.1656
	6	6	26	26	0.0803	0.1738
	7	7	27	27	0.0803	0.1826
	8	8	28	28	0.0803	0.1922
	9	9	29	29	0.0803	0.2027
	10	10	30	30	0.0803	0.2141
4	0.550	1.2493	M	HU	POTENTIAL 2D-ARY	OTHER ROTOR
	1	1	31	31	0.1062	0.1251
	2	2	32	32	0.1062	0.1304

Figure 42 : AEROEXEC output (ADJUST)

5	0.650	1.2361	3	33	0.1062	-0.0101	0.1359
			4	34	0.1062	-0.0101	0.1419
			5	35	0.1062	-0.0101	0.1462
			6	36	0.1062	-0.0101	0.1549
			7	37	0.1062	-0.0101	0.1620
			8	38	0.1062	-0.0101	0.1696
			9	39	0.1062	-0.0101	0.1778
			10	40	0.1062	-0.0101	0.1866
			M	HU	POTENTIAL 2D-ARY	OTHER ROTOR	
			1	41	0.1096	-0.0096	0.1156
6	0.750	1.2250	2	42	0.1096	-0.0096	0.1195
			3	43	0.1096	-0.0096	0.1238
			4	44	0.1096	-0.0096	0.1283
			5	45	0.1096	-0.0096	0.1329
			6	46	0.1096	-0.0096	0.1378
			7	47	0.1096	-0.0096	0.1429
			8	48	0.1096	-0.0096	0.1482
			9	49	0.1096	-0.0096	0.1537
			10	50	0.1096	-0.0096	0.1594
			M	HU	POTENTIAL 2D-ARY	OTHER ROTOR	
1	51	0.1130	-0.0075	0.1064			
7	0.850	1.2116	2	52	0.1130	-0.0075	0.1092
			3	53	0.1130	-0.0075	0.1121
			4	54	0.1130	-0.0075	0.1150
			5	55	0.1130	-0.0075	0.1180
			6	56	0.1130	-0.0075	0.1210
			7	57	0.1130	-0.0075	0.1240
			8	58	0.1130	-0.0075	0.1271
			9	59	0.1130	-0.0075	0.1301
			10	60	0.1130	-0.0075	0.1332
			M	HU	POTENTIAL 2D-ARY	OTHER ROTOR	
1	61	0.1159	-0.0063	0.0956			
8	0.950	1.1966	2	62	0.1159	-0.0063	0.0971
			3	63	0.1159	-0.0063	0.0986
			4	64	0.1159	-0.0063	0.1001
			5	65	0.1159	-0.0063	0.1015
			6	66	0.1159	-0.0063	0.1029
			7	67	0.1159	-0.0063	0.1042
			8	68	0.1159	-0.0063	0.1055
			9	69	0.1159	-0.0063	0.1067
			10	70	0.1159	-0.0063	0.1078
			M	HU	POTENTIAL 2D-ARY	OTHER ROTOR	
1	71	0.1179	-0.0048	0.0820			
9	1.1852	1.1852	2	72	0.1179	-0.0048	0.0825
			3	73	0.1179	-0.0048	0.0829
			4	74	0.1179	-0.0048	0.0832
			5	75	0.1179	-0.0048	0.0836
			6	76	0.1179	-0.0048	0.0838
			7	77	0.1179	-0.0048	0.0841
			8	78	0.1179	-0.0048	0.0843
			9	79	0.1179	-0.0048	0.0844
			10	80	0.1179	-0.0048	0.0845
			M	HU	POTENTIAL 2D-ARY	OTHER ROTOR	

NUMBER OF GEOMETRY STATIONS:	22
NUMBER OF STREAMLINES:	5

Figure 42 : AEROEXEC output (ADJUST, continued)

RADIUS		S.L. ANGLE	NUMBER OF STREAMLINES								
1	0.100	0.000	1	0.245	0.371	0.3143	0.242	4.015	1.2420	0.0000	0.5009
2	0.300	0.163	2	0.371	0.497	0.4383	0.342	2.049	1.2400	0.0000	0.4242
3	0.400	3.124	3	0.497	0.623	0.5831	0.442	2.005	1.2476	0.0000	0.5513
4	0.500	2.404	4	0.623	1.000	0.8329	1.924	0.654	1.2139	0.0000	2.3354
5	0.550	2.004									
6	0.600	1.702									
7	0.650	1.503									
8	0.700	1.244									
9	0.750	1.012									
10	0.800	0.792									
11	0.825	0.607									
12	0.850	0.504									
13	0.875	0.405									
14	0.900	0.391									
15	0.925	0.308									
16	0.950	0.208									
17	0.960	0.169									
18	0.970	0.127									
19	0.980	0.087									
20	0.990	0.050									
21	0.995	0.034									
22	1.000	0.020									

Figure 42 : AEROEXEC output (ADJUST, continued)

AFT ROTOR DATA AEROEXEC EXECCASE TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DAT
 MX = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VIIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 FRONT BLADE ANGLE = 40.07 DEG. - MEASURED - CP MATCH = 40.07
 REAR BLADE ANGLE = 40.54 DEG. - MEASURED - CP MATCH = 40.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

SUBROUTINE ADJUST

NUMBER OF SPANWISE MODES: 0
 NUMBER OF CHORDWISE PANELS 10

STATION V-AXIAL
 1 0.200 0.9978

M	MU	POTENTIAL 2D-ARY	OTHER ROTOR
1	1	0.0563	-0.1676
2	2	0.0563	-0.1536
3	3	0.0563	-0.1411
4	4	0.0563	-0.1299
5	5	0.0563	-0.1196
6	6	0.0563	-0.1102
7	7	0.0563	-0.1015
8	8	0.0563	-0.0933
9	9	0.0563	-0.0856
10	10	0.0563	-0.0784

M	MU	POTENTIAL 2D-ARY	OTHER ROTOR
1	11	0.0986	-0.1051
2	12	0.0986	-0.0939
3	13	0.0986	-0.0834
4	14	0.0986	-0.0738
5	15	0.0986	-0.0640
6	16	0.0986	-0.0564
7	17	0.0986	-0.0485
8	18	0.0986	-0.0411
9	19	0.0986	-0.0341
10	20	0.0986	-0.0274

M	MU	POTENTIAL 2D-ARY	OTHER ROTOR
1	21	0.1258	-0.0495
2	22	0.1258	-0.0495
3	23	0.1258	-0.0495
4	24	0.1258	-0.0495
5	25	0.1258	-0.0495
6	26	0.1258	-0.0495
7	27	0.1258	-0.0495
8	28	0.1258	-0.0495
9	29	0.1258	-0.0495
10	30	0.1258	-0.0495

M	MU	POTENTIAL 2D-ARY	OTHER ROTOR
1	31	0.1394	-0.0247
2	32	0.1394	-0.0247

Figure 42 : AEROEXEC output (ADJUST, continued)

RADIUS	S.L.	ANGLE
1	0.100	0.000
2	0.300	6.163
3	0.400	3.124
4	0.500	2.406
5	0.550	2.084
6	0.600	1.782
7	0.650	1.503
8	0.700	1.246
9	0.750	1.012
10	0.800	0.792
11	0.825	0.687
12	0.850	0.584
13	0.875	0.485
14	0.900	0.391
15	0.925	0.300
16	0.950	0.208
17	0.960	0.169
18	0.970	0.127
19	0.980	0.087
20	0.990	0.050
21	0.995	0.034
22	1.000	0.020

STREAMLINES BEFORE AND AFTER ADJUSTMENT					
N	FORWARD ROTOR		AFT ROTOR		NEW
	OLD	NEW	OLD	NEW	
1	0.2450	0.2450	0.2450	0.2450	0.2450
2	0.3708	0.3499	0.3708	0.3947	0.3947
3	0.4967	0.4597	0.4967	0.5381	0.5381
4	0.6225	0.5717	0.6225	0.6789	0.6789
5	1.0000	0.9232	1.0000	1.0639	1.0639

Figure 42 : AEROEXEC output (ADJUST, continued)

SUBROUTINE: CPHAP.
INDUCTION CALCULATION POINTS--REAR ROTOR ONTO FWD ROTOR

N	RADIUS	STREAMEUBE NO.	FLD CALC. POINT
1	0.2000	0	0.2000
2	0.3500	1	0.3949
3	0.4500	2	0.5254
4	0.5500	3	0.6516
5	0.6500	4	0.7773
6	0.7500	4	0.8843
7	0.8500	4	0.9995
8	0.9500	4	1.1147

Figure 43: AEROEXEC output (CPM/AP, rear rotor onto front rotor)

```

SUBROUTINE: CPMAP, DIAMETER RATIO: 1.0000
WAKE CALCULATION POINTS--FRONT ROTOR ONTO REAR ROTOR
RADIUS STREAHTUBE NO. WAKE CALC. POINT
1 0.2000 0 0.2000
2 0.3500 1 0.3166
3 0.4500 2 0.3922
4 0.5500 3 0.4692
5 0.6500 3 0.5487
6 0.7500 4 0.6334
7 0.8500 4 0.7202
8 0.9500 4 0.8070

```

Figure 44: AEROEXEC output (CPMAP, front rotor onto rear rotor)

PROPELLER EFFICIENCY PROGRAM IINTFRZ AEROEXEC EXECCASE TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DAT
 HK = 0.265, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

STATION	PHI	SIGNAL	SIGMA2	SIGNAL/SIGMA2	TWIST
1	0.2000	66.7165	1.088659	0.999148	69.7773
WHU VECTOR: FRONT ROTOR ONTO REAR					
STEADY TERM.					
HBAR	HU	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL
01	4.68365	-0.509608	0.430217	0.178157E-01	+1.5639
02	+0.375	-0.464361	0.325639	0.132034E-01	+1.4705
03	+0.406	-0.424132	0.232661	0.117356E-01	+1.3697
04	+0.436	-0.380096	0.151222	0.122764E-01	+1.2814
05	+0.471	-0.357793	0.793344E-01	0.110638E-01	+1.2034
06	+0.504	-0.331025	0.174664E-01	0.114891E-01	+1.1363
07	+0.537	-0.309323	-0.326903E-01	0.111472E-01	+1.0820
08	+0.569	-0.291574	-0.737140E-01	0.110833E-01	+1.0376
09	+0.602	-0.276843	-0.107760	0.105447E-01	+1.0008
10	+0.635	-0.264537	-0.136202	0.102774E-01	+0.9700
11	+0.668	-0.264537	-0.136202	0.102774E-01	+0.9700
WHU VECTOR: FRONT ROTOR ONTO REAR					
STEADY TERM.					
HBAR	HU	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL
01	4.68365	-0.509608	0.430217	0.178157E-01	+1.5639
02	+0.375	-0.464361	0.325639	0.132034E-01	+1.4705
03	+0.406	-0.424132	0.232661	0.117356E-01	+1.3697
04	+0.436	-0.380096	0.151222	0.122764E-01	+1.2814
05	+0.471	-0.357793	0.793344E-01	0.110638E-01	+1.2034
06	+0.504	-0.331025	0.174664E-01	0.114891E-01	+1.1363
07	+0.537	-0.309323	-0.326903E-01	0.111472E-01	+1.0820
08	+0.569	-0.291574	-0.737140E-01	0.110833E-01	+1.0376
09	+0.602	-0.276843	-0.107760	0.105447E-01	+1.0008
10	+0.635	-0.264537	-0.136202	0.102774E-01	+0.9700
11	+0.668	-0.264537	-0.136202	0.102774E-01	+0.9700

STATION	PHI	SIGNAL	SIGMA2	SIGNAL/SIGMA2	TWIST
2	0.3500	55.8089	1.208944	0.963830	67.1792
WHU VECTOR: FRONT ROTOR ONTO REAR					
STEADY TERM.					
HBAR	HU	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL
01	4.68365	-0.509608	0.430217	0.178157E-01	+1.5639
02	+0.375	-0.464361	0.325639	0.132034E-01	+1.4705
03	+0.406	-0.424132	0.232661	0.117356E-01	+1.3697
04	+0.436	-0.380096	0.151222	0.122764E-01	+1.2814
05	+0.471	-0.357793	0.793344E-01	0.110638E-01	+1.2034
06	+0.504	-0.331025	0.174664E-01	0.114891E-01	+1.1363
07	+0.537	-0.309323	-0.326903E-01	0.111472E-01	+1.0820
08	+0.569	-0.291574	-0.737140E-01	0.110833E-01	+1.0376
09	+0.602	-0.276843	-0.107760	0.105447E-01	+1.0008
10	+0.635	-0.264537	-0.136202	0.102774E-01	+0.9700
11	+0.668	-0.264537	-0.136202	0.102774E-01	+0.9700
WHU VECTOR: FRONT ROTOR ONTO REAR					
STEADY TERM.					
HBAR	HU	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL
01	4.68365	-0.509608	0.430217	0.178157E-01	+1.5639
02	+0.375	-0.464361	0.325639	0.132034E-01	+1.4705
03	+0.406	-0.424132	0.232661	0.117356E-01	+1.3697
04	+0.436	-0.380096	0.151222	0.122764E-01	+1.2814
05	+0.471	-0.357793	0.793344E-01	0.110638E-01	+1.2034
06	+0.504	-0.331025	0.174664E-01	0.114891E-01	+1.1363
07	+0.537	-0.309323	-0.326903E-01	0.111472E-01	+1.0820
08	+0.569	-0.291574	-0.737140E-01	0.110833E-01	+1.0376
09	+0.602	-0.276843	-0.107760	0.105447E-01	+1.0008
10	+0.635	-0.264537	-0.136202	0.102774E-01	+0.9700
11	+0.668	-0.264537	-0.136202	0.102774E-01	+0.9700

STATION	PHI	SIGNAL	SIGMA2	SIGNAL/SIGMA2	TWIST
3	0.4500	49.8363	1.308548	0.937624	62.1696
WHU VECTOR: FRONT ROTOR ONTO REAR					
STEADY TERM.					
HBAR	HU	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL
01	4.68365	-0.509608	0.430217	0.178157E-01	+1.5639
02	+0.375	-0.464361	0.325639	0.132034E-01	+1.4705
03	+0.406	-0.424132	0.232661	0.117356E-01	+1.3697
04	+0.436	-0.380096	0.151222	0.122764E-01	+1.2814
05	+0.471	-0.357793	0.793344E-01	0.110638E-01	+1.2034
06	+0.504	-0.331025	0.174664E-01	0.114891E-01	+1.1363
07	+0.537	-0.309323	-0.326903E-01	0.111472E-01	+1.0820
08	+0.569	-0.291574	-0.737140E-01	0.110833E-01	+1.0376
09	+0.602	-0.276843	-0.107760	0.105447E-01	+1.0008
10	+0.635	-0.264537	-0.136202	0.102774E-01	+0.9700
11	+0.668	-0.264537	-0.136202	0.102774E-01	+0.9700
WHU VECTOR: FRONT ROTOR ONTO REAR					
STEADY TERM.					
HBAR	HU	DOWNWASH	CHORDWISE	VISCOUS WAKE	AXIAL
01	4.68365	-0.509608	0.430217	0.178157E-01	+1.5639
02	+0.375	-0.464361	0.325639	0.132034E-01	+1.4705
03	+0.406	-0.424132	0.232661	0.117356E-01	+1.3697
04	+0.436	-0.380096	0.151222	0.122764E-01	+1.2814
05	+0.471	-0.357793	0.793344E-01	0.110638E-01	+1.2034
06	+0.504	-0.331025	0.174664E-01	0.114891E-01	+1.1363
07	+0.537	-0.309323	-0.326903E-01	0.111472E-01	+1.0820
08	+0.569	-0.291574	-0.737140E-01	0.110833E-01	+1.0376
09	+0.602	-0.276843	-0.107760	0.105447E-01	+1.0008
10	+0.635	-0.264537	-0.136202	0.102774E-01	+0.9700
11	+0.668	-0.264537	-0.136202	0.102774E-01	+0.9700

Figure 45 : AEROEXEC output (steady WMU vector calculation)

WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
4	0.5500	44.2483	1.433139	1.554253	0.922076	57.1517			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
5	0.6500	39.5681	1.569870	1.725487	0.909813	52.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
6	0.7500	35.5371	1.720490	1.905913	0.902712	48.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
7	0.8500	32.1434	1.879557	2.093157	0.897553	45.2894			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
8	0.9500	29.1000	2.040000	2.290000	0.890000	42.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
9	1.0500	26.1000	2.150000	2.400000	0.880000	40.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
10	1.1500	23.1000	2.250000	2.500000	0.870000	37.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
11	1.2500	20.1000	2.350000	2.600000	0.860000	35.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
12	1.3500	17.1000	2.450000	2.700000	0.850000	32.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
13	1.4500	14.1000	2.550000	2.800000	0.840000	30.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
14	1.5500	11.1000	2.650000	2.900000	0.830000	27.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
15	1.6500	8.1000	2.750000	3.000000	0.820000	25.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
16	1.7500	5.1000	2.850000	3.100000	0.810000	22.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
17	1.8500	2.1000	2.950000	3.200000	0.800000	20.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
18	1.9500	0.1000	3.050000	3.300000	0.790000	17.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
19	2.0500	0.0000	3.150000	3.400000	0.780000	15.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
20	2.1500	0.0000	3.250000	3.500000	0.770000	12.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
21	2.2500	0.0000	3.350000	3.600000	0.760000	10.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
22	2.3500	0.0000	3.450000	3.700000	0.750000	7.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
23	2.4500	0.0000	3.550000	3.800000	0.740000	5.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
24	2.5500	0.0000	3.650000	3.900000	0.730000	2.5000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
25	2.6500	0.0000	3.750000	4.000000	0.720000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
26	2.7500	0.0000	3.850000	4.100000	0.710000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
27	2.8500	0.0000	3.950000	4.200000	0.700000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
28	2.9500	0.0000	4.050000	4.300000	0.690000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
29	3.0500	0.0000	4.150000	4.400000	0.680000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
30	3.1500	0.0000	4.250000	4.500000	0.670000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
31	3.2500	0.0000	4.350000	4.600000	0.660000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
32	3.3500	0.0000	4.450000	4.700000	0.650000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
33	3.4500	0.0000	4.550000	4.800000	0.640000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
34	3.5500	0.0000	4.650000	4.900000	0.630000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
35	3.6500	0.0000	4.750000	5.000000	0.620000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
36	3.7500	0.0000	4.850000	5.100000	0.610000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
37	3.8500	0.0000	4.950000	5.200000	0.600000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
38	3.9500	0.0000	5.050000	5.300000	0.590000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
39	4.0500	0.0000	5.150000	5.400000	0.580000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
40	4.1500	0.0000	5.250000	5.500000	0.570000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
41	4.2500	0.0000	5.350000	5.600000	0.560000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
42	4.3500	0.0000	5.450000	5.700000	0.550000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
43	4.4500	0.0000	5.550000	5.800000	0.540000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
44	4.5500	0.0000	5.650000	5.900000	0.530000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
45	4.6500	0.0000	5.750000	6.000000	0.520000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
46	4.7500	0.0000	5.850000	6.100000	0.510000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
47	4.8500	0.0000	5.950000	6.200000	0.500000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
48	4.9500	0.0000	6.050000	6.300000	0.490000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
49	5.0500	0.0000	6.150000	6.400000	0.480000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
50	5.1500	0.0000	6.250000	6.500000	0.470000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
51	5.2500	0.0000	6.350000	6.600000	0.460000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
52	5.3500	0.0000	6.450000	6.700000	0.450000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
53	5.4500	0.0000	6.550000	6.800000	0.440000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
54	5.5500	0.0000	6.650000	6.900000	0.430000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
55	5.6500	0.0000	6.750000	7.000000	0.420000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
56	5.7500	0.0000	6.850000	7.100000	0.410000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
57	5.8500	0.0000	6.950000	7.200000	0.400000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
58	5.9500	0.0000	7.050000	7.300000	0.390000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
59	6.0500	0.0000	7.150000	7.400000	0.380000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
60	6.1500	0.0000	7.250000	7.500000	0.370000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
61	6.2500	0.0000	7.350000	7.600000	0.360000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
62	6.3500	0.0000	7.450000	7.700000	0.350000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
63	6.4500	0.0000	7.550000	7.800000	0.340000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
64	6.5500	0.0000	7.650000	7.900000	0.330000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
65	6.6500	0.0000	7.750000	8.000000	0.320000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
66	6.7500	0.0000	7.850000	8.100000	0.310000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
67	6.8500	0.0000	7.950000	8.200000	0.300000	0.0000			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
68	6.9500	0.0000	8						

STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
5	0.6500	39.5601	1.569870	1.725487	0.909813	52.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
6	0.7500	34.5601	1.869870	1.925487	0.809813	47.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
7	0.8500	29.5601	2.169870	2.181487	0.709813	42.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
8	0.9500	24.5601	2.469870	2.241487	0.609813	37.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
9	1.0500	19.5601	2.769870	2.311487	0.509813	32.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
10	1.1500	14.5601	3.069870	2.381487	0.409813	27.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
11	1.2500	9.5601	3.369870	2.451487	0.309813	22.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
12	1.3500	4.5601	3.669870	2.521487	0.209813	17.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
13	1.4500	-0.4601	3.969870	2.591487	0.109813	12.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
14	1.5500	-5.4601	4.269870	2.661487	0.009813	7.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
15	1.6500	-10.4601	4.569870	2.731487	-0.099813	2.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
16	1.7500	-15.4601	4.869870	2.801487	-0.199813	-2.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
17	1.8500	-20.4601	5.169870	2.871487	-0.299813	-7.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
18	1.9500	-25.4601	5.469870	2.941487	-0.399813	-12.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
19	2.0500	-30.4601	5.769870	3.011487	-0.499813	-17.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
20	2.1500	-35.4601	6.069870	3.081487	-0.599813	-22.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
21	2.2500	-40.4601	6.369870	3.151487	-0.699813	-27.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
22	2.3500	-45.4601	6.669870	3.221487	-0.799813	-32.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
23	2.4500	-50.4601	6.969870	3.291487	-0.899813	-37.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
24	2.5500	-55.4601	7.269870	3.361487	-0.999813	-42.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
25	2.6500	-60.4601	7.569870	3.431487	-1.099813	-47.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
26	2.7500	-65.4601	7.869870	3.501487	-1.199813	-52.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
27	2.8500	-70.4601	8.169870	3.571487	-1.299813	-57.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
28	2.9500	-75.4601	8.469870	3.641487	-1.399813	-62.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
29	3.0500	-80.4601	8.769870	3.711487	-1.499813	-67.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
30	3.1500	-85.4601	9.069870	3.781487	-1.599813	-72.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
31	3.2500	-90.4601	9.369870	3.851487	-1.699813	-77.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
32	3.3500	-95.4601	9.669870	3.921487	-1.799813	-82.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
33	3.4500	-100.4601	9.969870	3.991487	-1.899813	-87.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
34	3.5500	-105.4601	10.269870	4.061487	-1.999813	-92.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
35	3.6500	-110.4601	10.569870	4.131487	-2.099813	-97.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
36	3.7500	-115.4601	10.869870	4.201487	-2.199813	-102.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
37	3.8500	-120.4601	11.169870	4.271487	-2.299813	-107.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
38	3.9500	-125.4601	11.469870	4.341487	-2.399813	-112.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
39	4.0500	-130.4601	11.769870	4.411487	-2.499813	-117.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
40	4.1500	-135.4601	12.069870	4.481487	-2.599813	-122.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
41	4.2500	-140.4601	12.369870	4.551487	-2.699813	-127.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
42	4.3500	-145.4601	12.669870	4.621487	-2.799813	-132.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
43	4.4500	-150.4601	12.969870	4.691487	-2.899813	-137.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
44	4.5500	-155.4601	13.269870	4.761487	-2.999813	-142.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
45	4.6500	-160.4601	13.569870	4.831487	-3.099813	-147.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
46	4.7500	-165.4601	13.869870	4.901487	-3.199813	-152.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
47	4.8500	-170.4601	14.169870	4.971487	-3.299813	-157.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
48	4.9500	-175.4601	14.469870	5.041487	-3.399813	-162.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
49	5.0500	-180.4601	14.769870	5.111487	-3.499813	-167.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
50	5.1500	-185.4601	15.069870	5.181487	-3.599813	-172.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
51	5.2500	-190.4601	15.369870	5.251487	-3.699813	-177.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
52	5.3500	-195.4601	15.669870	5.321487	-3.799813	-182.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
53	5.4500	-200.4601	15.969870	5.391487	-3.899813	-187.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
54	5.5500	-205.4601	16.269870	5.461487	-3.999813	-192.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
55	5.6500	-210.4601	16.569870	5.531487	-4.099813	-197.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
56	5.7500	-215.4601	16.869870	5.601487	-4.199813	-202.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
57	5.8500	-220.4601	17.169870	5.671487	-4.299813	-207.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
58	5.9500	-225.4601	17.469870	5.741487	-4.399813	-212.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
59	6.0500	-230.4601	17.769870	5.811487	-4.499813	-217.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
60	6.1500	-235.4601	18.069870	5.881487	-4.599813	-222.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
61	6.2500	-240.4601	18.369870	5.951487	-4.699813	-227.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
62	6.3500	-245.4601	18.669870	6.021487	-4.799813	-232.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
63	6.4500	-250.4601	18.969870	6.091487	-4.899813	-237.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
64	6.5500	-255.4601	19.269870	6.161487	-4.999813	-242.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
65	6.6500	-260.4601	19.569870	6.231487	-5.099813	-247.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
66	6.7500	-265.4601	19.869870	6.301487	-5.199813	-252.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
67	6.8500	-270.4601	20.169870	6.371487	-5.299813	-257.5466			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
68	6.9500	-275.4601	20.469870	6.441487</					

WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
6	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
7	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
8	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
9	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
10	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
11	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
12	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
13	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
14	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
15	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
16	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
17	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
18	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
19	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
20	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
21	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
22	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
23	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
24	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
25	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
26	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
27	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
28	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
29	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
30	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
31	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
32	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
33	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
34	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
35	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
36	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
37	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
38	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
39	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
40	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
41	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
42	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
43	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
44	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
45	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
46	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
47	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
48	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
49	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
50	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
51	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
52	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
53	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
54	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
55	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
56	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
57	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
58	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
59	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
60	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
61	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
62	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
63	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
64	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
65	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
66	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
67	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
68	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
69	0.7500	35.5371	1.720490	1.905913	0.902712	46.5225			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEAD									

WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
7	0.8500	32.1434	1.679557	2.093157	0.897553	45.2894			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
14	1.5500	0.1434	3.6981	3.9581	0.716691	-0.0461			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
15	1.6500	0.0434	3.9581	4.2181	0.686510	-0.0287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
16	1.7500	0.0034	4.2181	4.4981	0.656510	-0.0187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
17	1.8500	0.0034	4.4981	4.7781	0.626510	-0.0087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
18	1.9500	0.0034	4.7781	5.0581	0.596510	-0.0017			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
19	2.0500	0.0034	5.0581	5.3381	0.566510	0.0087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
20	2.1500	0.0034	5.3381	5.6181	0.536510	0.0187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
21	2.2500	0.0034	5.6181	5.8981	0.506510	0.0287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
22	2.3500	0.0034	5.8981	6.1781	0.476510	0.0387			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
23	2.4500	0.0034	6.1781	6.4581	0.446510	0.0487			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
24	2.5500	0.0034	6.4581	6.7381	0.416510	0.0587			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
25	2.6500	0.0034	6.7381	7.0181	0.386510	0.0687			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
26	2.7500	0.0034	7.0181	7.2981	0.356510	0.0787			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
27	2.8500	0.0034	7.2981	7.5781	0.326510	0.0887			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
28	2.9500	0.0034	7.5781	7.8581	0.296510	0.0987			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
29	3.0500	0.0034	7.8581	8.1381	0.266510	0.1087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
30	3.1500	0.0034	8.1381	8.4181	0.236510	0.1187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
31	3.2500	0.0034	8.4181	8.6981	0.206510	0.1287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
32	3.3500	0.0034	8.6981	8.9781	0.176510	0.1387			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
33	3.4500	0.0034	8.9781	9.2581	0.146510	0.1487			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
34	3.5500	0.0034	9.2581	9.5381	0.116510	0.1587			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
35	3.6500	0.0034	9.5381	9.8181	0.086510	0.1687			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
36	3.7500	0.0034	9.8181	10.0981	0.056510	0.1787			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
37	3.8500	0.0034	10.0981	10.3781	0.026510	0.1887			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
38	3.9500	0.0034	10.3781	10.6581	-0.003510	0.1987			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
39	4.0500	0.0034	10.6581	10.9381	-0.033510	0.2087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
40	4.1500	0.0034	10.9381	11.2181	-0.063510	0.2187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
41	4.2500	0.0034	11.2181	11.4981	-0.093510	0.2287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
42	4.3500	0.0034	11.4981	11.7781	-0.123510	0.2387			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
43	4.4500	0.0034	11.7781	12.0581	-0.153510	0.2487			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
44	4.5500	0.0034	12.0581	12.3381	-0.183510	0.2587			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
45	4.6500	0.0034	12.3381	12.6181	-0.213510	0.2687			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
46	4.7500	0.0034	12.6181	12.8981	-0.243510	0.2787			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
47	4.8500	0.0034	12.8981	13.1781	-0.273510	0.2887			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
48	4.9500	0.0034	13.1781	13.4581	-0.303510	0.2987			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
49	5.0500	0.0034	13.4581	13.7381	-0.333510	0.3087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
50	5.1500	0.0034	13.7381	14.0181	-0.363510	0.3187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
51	5.2500	0.0034	14.0181	14.2981	-0.393510	0.3287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
52	5.3500	0.0034	14.2981	14.5781	-0.423510	0.3387			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
53	5.4500	0.0034	14.5781	14.8581	-0.453510	0.3487			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
54	5.5500	0.0034	14.8581	15.1381	-0.483510	0.3587			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
55	5.6500	0.0034	15.1381	15.4181	-0.513510	0.3687			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
56	5.7500	0.0034	15.4181	15.6981	-0.543510	0.3787			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
57	5.8500	0.0034	15.6981	15.9781	-0.573510	0.3887			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
58	5.9500	0.0034	15.9781	16.2581	-0.603510	0.3987			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
59	6.0500	0.0034	16.2581	16.5381	-0.633510	0.4087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
60	6.1500	0.0034	16.5381	16.8181	-0.663510	0.4187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
61	6.2500	0.0034	16.8181	17.0981	-0.693510	0.4287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
62	6.3500	0.0034	17.0981	17.3781	-0.723510	0.4387			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
63	6.4500	0.0034	17.3781	17.6581	-0.753510	0.4487			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
64	6.5500	0.0034	17.6581	17.9381	-0.783510	0.4587			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
65	6.6500	0.0034	17.9381	18.2181	-0.813510	0.4687			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
66	6.7500	0.0034	18.2181	18.4981	-0.843510	0.4787			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
67	6.8500	0.0034	18.4981	18.7781	-0.873510	0.4887			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
68	6.9500	0.0034	18.7781	19.0581	-0.903510	0.4987			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
69	7.0500	0.0034	19.0581	19.3381	-0.933510	0.5087			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
70	7.1500	0.0034	19.3381	19.6181	-0.963510	0.5187			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
71	7.2500	0.0034	19.6181	19.8981	-0.993510	0.5287			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
72	7.3500	0.0034	19.8981	20.1781	-1.023510	0.5387			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
73	7.4500	0.0034	20.1781	20.4581	-1.053510	0.5487			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
74	7.5500	0.0034	20.4581	20.7381	-1.083510	0.5587			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
75	7.6500	0.0034	20.7381	21.0181	-1.113510	0.5687			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
76	7.7500	0.0034	21.0181	21.2981	-1.143510	0.5787			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
77	7.8500	0.0034	21.2981	21.5781	-1.173510	0.5887			
WMU VECTOR: FRONT ROTOR ONTO REAR									
STEADY TERM.									
STATION	PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST				
78	7.9500	0.0034	21.57						

Figure 45 : AEROEXEC output (steady WMU) vector calculation, continued)

07	+0.438	67	7.43804	-0.152106	-0.173323	0.870494E-02	+1.0319	-0.0957
08	+0.660	68	6.72863	-0.168635	-0.162993	0.855111E-02	+1.0515	-0.0767
09	+0.681	69	6.04487	-0.184478	-0.153092	0.846944E-02	+1.0703	-0.0586
10	+0.703	70	5.55129	-0.195908	-0.145949	0.827179E-02	+1.0838	-0.0454
WMU VECTOR: FRONT ROTOR ONTO REAR								
STEADY TERM.								
STATION		PHI	SIGMA1	SIGMA2	SIGMA1/SIGMA2	TWIST		
0		29.2876	2.046179	2.205543	0.094395	42.5927		
HBAR	XHBR	HU	WMU(STEADY)	DOWNHSH	CHORDWISE	VISCOUS WAKE	AXIAL	SWIRL
01	+0.566	71	7.76135	-0.573701E-01	-0.168252	0.987988E-02	+0.9629	-0.1496
02	+0.500	72	7.21802	-0.698231E-01	-0.161305	0.976601E-02	+0.9772	-0.1365
03	+0.615	73	6.64858	-0.828877E-01	-0.154017	0.961734E-02	+0.9922	-0.1227
04	+0.629	74	6.00784	-0.976118E-01	-0.145803	0.949361E-02	+1.0092	-0.1071
05	+0.643	75	5.43948	-0.110871	-0.138406	0.937453E-02	+1.0244	-0.0932
06	+0.658	76	5.06148	-0.119765	-0.133444	0.925981E-02	+1.0346	-0.0837
07	+0.672	77	4.74665	-0.126400	-0.129699	0.914919E-02	+1.0424	-0.0766
08	+0.687	78	4.40312	-0.134328	-0.125320	0.904243E-02	+1.0514	-0.0683
09	+0.701	79	4.02114	-0.143073	-0.120442	0.893932E-02	+1.0615	-0.0591
10	+0.715	80	3.67044	-0.151096	-0.115966	0.883964E-02	+1.0707	-0.0506

Figure 45 : AEROEXEC output (steady WMU vector calculation, continued)

UNSTEADY: FRONT ROTOR ON REAR ROTOR
 HARMONIC OF BLADE PASS FREQUENCY: 1
 NUMBER OF BLADES: 6
 HARMONIC OF SHAFT FREQUENCY: 6
 Q-ORDER: 12.0326305

WMU VECTOR:									
STATION	WAKE	PNT	PHI	SIGMA1	SIGMA2	SIGNAL/SIGMA2	TWIST		
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)									
1	0.200	0.200	+66.717	+1.0687	+1.0896	+0.9991	+69.677		
HBAR	MU	XHBAR				DPHI	WMU	DOWNWASH	CHORDWISE
	1	01	0.373			0.549	(0.496, -0.933)	(-0.011, 0.006)	(0.034, -0.032)
	2	02	0.406			0.681	(0.019, -0.799)	(-0.010, 0.012)	(0.007, -0.025)
	3	03	0.438			0.812	(-0.063, -0.873)	(-0.005, 0.019)	(-0.004, -0.015)
	4	04	0.471			0.943	(-0.059, -0.959)	(0.006, 0.024)	(-0.008, -0.005)
	5	05	0.504			1.074	(0.235, -1.153)	(0.018, 0.024)	(-0.009, 0.005)
	6	06	0.537			1.205	(0.549, -0.962)	(0.029, 0.019)	(-0.008, 0.005)
	7	07	0.569			1.336	(0.639, -0.820)	(0.037, 0.011)	(-0.005, 0.001)
	8	08	0.602			1.467	(0.927, -0.869)	(0.043, -0.002)	(-0.003, -0.002)
	9	09	0.635			1.599	(1.064, -0.291)	(0.035, -0.008)	(-0.001, -0.004)
	10	10	0.668			1.730	(-0.250, 0.652)	(0.019, 0.018)	(-0.001, -0.004)
WMU VECTOR:									

WMU VECTOR:									
STATION	WAKE	PNT	PHI	SIGMA1	SIGMA2	SIGNAL/SIGMA2	THWIST		
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)									
2	0.350	0.316	+55.809	+1.2089	+1.2543	+0.9638	+67.179		
HBAR MU	XHBAR		DPHI	WMU	DOWNWASH	CHORDWISE	VISCOUS WAKE		
1	11	0.335	0.484	(1.996, -7.026)	(-0.062, 0.021)	(0.170, -0.151)	0.052		
2	12	0.369	0.597	(1.311, -5.418)	(-0.061, 0.058)	(0.065, -0.156)	0.049		
3	13	0.402	0.710	(0.977, -4.365)	(-0.041, 0.104)	(-0.002, -0.128)	0.047		
4	14	0.436	0.822	(0.504, -3.666)	(0.008, 0.149)	(-0.040, -0.090)	0.044		
5	15	0.469	0.935	(-0.269, -3.327)	(0.091, 0.177)	(-0.057, -0.055)	0.042		
6	16	0.503	1.047	(-1.682, -3.710)	(0.207, 0.165)	(-0.058, -0.027)	0.040		
7	17	0.537	1.160	(-3.425, -5.683)	(0.344, 0.085)	(-0.050, -0.006)	0.039		
8	18	0.570	1.273	(-4.547, -9.844)	(0.470, -0.089)	(-0.039, 0.008)	0.037		
9	19	0.604	1.385	(-3.638, -16.383)	(0.550, -0.372)	(-0.027, 0.016)	0.036		
10	20	0.637	1.498	(0.881, -24.457)	(0.447, -0.754)	(-0.015, 0.019)	0.034		

WMU VECTOR:									
STATION	WAKE	PNT	PHI	SIGMA1	SIGMA2	SIGNAL/SIGMA2	THWIST		
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)									
3	0.450	0.392	+49.836	+1.3085	+1.3956	+0.9376	+62.170		
MBAR	MU	XHBAR	DPHI		MMU			DOWNWASH	CHORDWISE
1	21	0.322	0.447	(-7.997, -16.333)	(-0.100, 0.040)	(0.222, -0.381)	0.181		
2	22	0.357	0.562	(-2.709, -16.113)	(-0.099, 0.103)	(0.076, -0.344)	0.163		
3	23	0.391	0.677	(2.354, -14.238)	(-0.060, 0.172)	(-0.027, -0.281)	0.147		
4	24	0.426	0.792	(5.930, -10.399)	(0.028, 0.237)	(-0.091, -0.207)	0.134		
5	25	0.460	0.906	(6.739, -5.688)	(0.169, 0.268)	(-0.122, -0.134)	0.122		
6	26	0.495	1.021	(4.448, -1.864)	(0.358, 0.229)	(-0.128, -0.069)	0.111		
7	27	0.529	1.136	(-0.239, -0.826)	(0.568, 0.074)	(-0.116, -0.018)	0.101		
8	28	0.564	1.251	(-5.547, -3.929)	(0.737, -0.236)	(-0.093, 0.018)	0.092		
9	29	0.598	1.365	(-9.257, -11.629)	(0.764, -0.723)	(-0.066, 0.039)	0.084		
10	30	0.633	1.480	(-8.865, -23.534)	(0.514, -1.347)	(-0.039, 0.048)	0.077		
WMU VECTOR:									

Figure 46 : AEROEXEC output (unsteady WMU vector calculation)

COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)				+0.9221		+57.152		DOWNHILL		CHORDWISE		VISCIOUS WAKE	
4	0.550	0.477	+44.240	+1.4331	+1.5543	DPHI	WHU						
			MDAR	MU	XHDAR								
			1	31	0.334	0.496	(5.510, -35.425)	(-0.135,	0.0961	(0.401,	-0.677)	0.150	
			2	32	0.360	0.610	(13.490, -26.713)	(-0.106,	0.1051	(0.141,	-0.616)	0.144	
			3	33	0.403	0.723	(18.568, -17.153)	(-0.084,	0.0942	(-0.042,	-0.507)	0.132	
			4	34	0.457	0.836	(19.091, -7.913)	(0.122,	0.341	(-0.160,	-0.375)	0.121	
			5	35	0.471	0.949	(16.523, -5.214)	(6.320,	0.339)	(-0.221,	-0.242)	0.111	
			6	36	0.505	1.063	(11.126, 5.117)	(0.583,	0.221)	(-0.230,	-0.123)	0.102	
			7	37	0.539	1.176	(3.984, 6.732)	(0.799,	-0.051)	(-0.213,	-0.029)	0.094	
			8	38	0.573	1.289	(-2.941, 3.968)	(0.938,	0.504)	(-0.171,	0.036)	0.087	
			9	39	0.607	1.402	(-7.506, -3.041)	(0.862,	-1.131)	(-0.121,	0.074)	0.080	
			10	40	0.641	1.516	(-7.665, -12.977)	(0.422,	-1.854)	(-0.069,	0.079)	0.074	

WNU VECTOR:											
STATION	WAKE	PNT	PHI	SIGNAL	SIGHA2	SIGNAL/SIGHA2	TWIST				
COMPLEX NUMBERS PRINTED AS (REAL, IMAGINARY)											
5	0.650	0.562	+39.568	-1.5699	+1.7255	+0.9090	+52.547				
				HBAR	HU	XHBAR					
				1	41	0.374	0.642	(39.297, -29.592)	(-0.101, 0.226)	(0.309, -0.931)	0.104
				2	42	0.406	0.746	(39.099, -13.462)	(-0.011, 0.308)	(0.021, -0.801)	0.098
				3	43	0.737	0.851	(34.925, -0.857)	(0.132, 0.362)	(-0.184, -0.627)	0.091
				4	44	0.955	0.955	(28.430, 8.445)	(0.322, 0.358)	(-0.305, -0.458)	0.086
				5	45	0.500	1.059	(20.496, 14.556)	(0.543, 0.267)	(-0.351, -0.081)	0.081
				6	46	0.531	1.163	(12.063, 17.442)	(0.760, 0.058)	(-0.344, -0.111)	0.076
				7	47	0.562	1.267	(3.994, 17.165)	(0.917, -0.286)	(-0.300, 0.004)	0.072
				8	48	0.593	1.372	(-2.515, 13.733)	(0.945, -0.763)	(-0.230, 0.080)	0.068
				9	49	0.625	1.476	(-6.327, 8.550)	(0.745, -1.339)	(-0.154, 0.122)	0.065
				10	50	0.656	1.580	(-7.399, 2.945)	(0.255, -1.941)	(-0.087, 0.136)	0.061

WNU VECTOR:									
STATION		WAKE		PNT		PIII		SIGNAL	
COMPLEX NUMBERS		PRINTED		AS (REAL, IMAGINARY)		SIGNAL/SIGMA2		TWIST	
6	0.750	0.651	+	1.7205	+1.9059	+	0.9027	+	448.523
MBAR	HU	XIBAR	HU	XIBAR	HU	XIBAR	HU	XIBAR	HU
1	51	0.436	0.059	(47.211,	14.079)	(0.103,	0.336)	(-0.127,	-0.911)
2	52	0.463	0.949	(36.036,	21.543)	(0.243,	0.340)	(-0.310,	0.009
3	53	0.490	1.040	(25.661,	25.512)	(0.402,	0.293)	(-0.425,	-0.468)
4	54	0.517	1.130	(16.437,	27.018)	(0.562,	0.181)	(-0.464,	-0.292)
5	55	0.544	1.220	(8.162,	26.409)	(0.702,	-0.006)	(-0.441,	-0.126)
6	56	0.571	1.310	(1.447,	24.290)	(0.794,	-0.267)	(-0.381,	0.008
7	57	0.598	1.400	(-3.764,	21.661)	(0.804,	-0.596)	(-0.307,	0.094)
8	58	0.625	1.490	(-7.851,	10.729)	(0.697,	0.969)	(-0.225,	0.150)
9	59	0.652	1.500	(-11.771,	15.712)	(0.642,	-1.353)	(-0.145,	0.007
10	60	0.679	1.670	(-13.796,	12.692)	(0.020,	-1.699)	(-0.075,	0.178)

[illegible]

Figure 46 : AEROEXEC output (unsteady WMU vector calculation, continued)

NOISE CALCULATION OUTPUT : NO2OUT NOIZEXEC EXECCASE TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DATA
 MX = 0.245, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 436 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

NOISE PROGRAM EXECUTION TIME

CPU TIME AT START = 726.941 SEC
 CPU TIME AT END = 733.668 SEC
 NET TIME = 6.719 SEC

OBSERVER LOCATIONS

DIRECTIVITY POINTS AT ALTITUDE OR SIDELINE DISTANCE, 6.126 FT.

DISTANCE FORWARD OF PLANE OF ROTATION (RETARDED) RE FRONT ROTOR						
6.346	4.645	2.573	0.4170	-1.447	-4.112	-8.773
DISTANCE FORWARD OF PLANE OF ROTATION (VISUAL) RE FRONT ROTOR						
4.021	2.689	0.8137	-1.209	-3.114	-6.066	-11.61
RADIATION ANGLE FROM FLIGHT DIRECTION - DEGREES RE FRONT ROTOR						
43.90	52.80	67.20	86.10	103.3	123.9	145.1
VISUAL RADIATION ANGLE - DEGREES RE FRONT ROTOR						
56.69	66.91	82.43	101.2	117.0	134.7	152.2
FRONT ROTOR AZIMUTHAL OBSERVER ANGLE IS 90.0 DEGREES						
REAR ROTOR POSITIONS OFFSET FROM FRONT ROTOR OBSERVER POSITIONS BY 0.2578 = FRONT RADIUS						
DISTANCE FORWARD OF PLANE OF ROTATION (RETARDED) RE REAR ROTOR						
7.014	5.276	3.166	0.9598	-0.9464	-3.651	-8.340
DISTANCE FORWARD OF PLANE OF ROTATION (VISUAL) RE REAR ROTOR						
4.547	3.135	1.340	-0.6026	-2.580	-5.540	-11.08
RADIATION ANGLE FROM FLIGHT DIRECTION - DEGREES RE REAR ROTOR						
41.11	49.23	62.45	81.09	98.79	120.8	143.7
VISUAL RADIATION ANGLE - DEGREES RE REAR ROTOR						
53.39	62.88	77.65	96.36	112.9	132.2	151.1
REAR ROTOR AZIMUTHAL OBSERVER ANGLE IS 90.0 DEGREES						

AMBIENT ATMOSPHERIC CONDITIONS

TEMPERATURE = 56.18
 PRESSURE / SEA LEVEL = 0.9598
 LOCAL SPEED OF SOUND = 1113.36 FEET PER SECOND

Figure 47:NOIZEXEC output (observer position summary)

FRONT ROTOR OPERATING CONDITIONS

0.2658 FLIGHT MACH NUMBER, 0.5702 TIP ROTATIONAL MACH NUMBER, 0.6288 TIP RELATIVE MACH NUMBER,
2.1514 MT / MK, 592.37 BPF, 2.0467 FOOT DIAMETER

REAR ROTOR OPERATING CONDITIONS

0.2658 FLIGHT MACH NUMBER, 0.5735 TIP ROTATIONAL MACH NUMBER, 0.6316 TIP RELATIVE MACH NUMBER,
2.1633 MT / MK, 496.33 BPF, 2.0467 FOOT DIAMETER

Figure 48:NOIZEXEC output (front and rear rotor operating conditions)

UCAP FOR CR-2 INPUT -- R252INPT.DAT
 MX = 0.245, J = 1.44, TEMP = 56.2, P/PREF = .9627, VTIP = 636 FPS
 6X5 CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

RESULTS AT OBSERVER POSITION 1 : VISUAL COORDINATES RETARDED COORDINATES
 X POSITION ANGLE X POSITION ANGLE
 FRONT ROTOR : 4.82 54.69 6.36 43.90
 REAR ROTOR : 4.55 53.39 7.01 41.11

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF 1 TIMES BLADE PASSING FREQUENCY

RADIATION FREQ	M COUNTER	K COUNTER	DB	PHASE	FRONT ROTOR P REAL	P IMAG	RMS PA	DB	PHASE	REAR ROTOR P REAL	P IMAG	RMS PA
486.42	2	-1	-65.8	8.8	0.0000	0.0000	0.0000					
** FRONT ROTOR **												
* STEADY NOISE *												
592.37	1	8	99.7	101.2	-0.3768	1.8963	1.9352	102.9	295.6	1.2027	-2.5050	2.7787
STEADY THICKNESS												
			92.2	162.5	-0.7775	0.2445	0.8150					
QUADRUPOLE												
			-200.0	0.0	0.0000	0.0000	0.0000					
RADIAL LOADING												
			-200.0	0.0	0.0000	0.0000	0.0000					
TOTAL NOISE												
			101.7	110.3	-1.1535	2.1408	2.4318					
** REAR ROTOR **												
* STEADY NOISE *												
496.33	0	1	110.4	202.7	-15.3091	-6.4173	16.5997	84.3	332.2	0.3647	-0.1911	0.4122
STEADY THICKNESS												
								85.0	323.5	0.3125	-0.2312	0.3887
QUADRUPOLE												
								-200.0	0.0	0.0000	0.0000	0.0000
RADIAL LOADING												
								-200.0	0.0	0.0000	0.0000	0.0000
TOTAL STEADY NOISE												
								92.0	328.0	0.4772	-0.4232	0.7986
400.29	-1	2						-134.0	54.6	0.0000	0.0000	0.0000
304.24	-2	3						-200.0	0.0	0.0000	0.0000	0.0000

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF 2 TIMES BLADE PASSING FREQUENCY

RADIATION FREQ	M COUNTER	K COUNTER	DB	PHASE	FRONT ROTOR P REAL	P IMAG	RMS PA	DB	PHASE	REAR ROTOR P REAL	P IMAG	RMS PA
1200.79	3	-1	-70.3	301.3	0.0000	0.0000	0.0000					
** FRONT ROTOR **												
* STEADY NOISE *												
1184.75	2	8	63.4	340.5	0.0209	-0.0059	0.0295	47.9	252.9	-0.0015	-0.0048	0.0050
STEADY THICKNESS												
			62.9	104.0	-0.0071	0.0270	0.0279					
QUADRUPOLE												
			-200.0	0.0	0.0000	0.0000	0.0000					
RADIAL LOADING												
			-200.0	0.0	0.0000	0.0000	0.0000					
TOTAL NOISE												
			63.6	44.0	0.0210	0.0211	0.0305					
1088.70	1	1	148.9	170.6	-549.2166	91.3227	556.7573	151.6	293.6	305.2954	-700.2676	763.9241
** REAR ROTOR **												
* STEADY NOISE *												
992.66	0	2						47.1	99.7	-0.0000	0.0045	0.0046
STEADY THICKNESS												
								60.9	137.7	-0.0163	0.0149	0.0221
QUADRUPOLE												
								-200.0	0.0	0.0000	0.0000	0.0000
RADIAL LOADING												
								-200.0	0.0	0.0000	0.0000	0.0000
TOTAL STEADY NOISE												
								62.2	131.5	-0.0171	0.0193	0.0258
896.62	-1	3						-123.0	243.6	0.0000	0.0000	0.0000
800.57	-2	4						-200.0	0.0	0.0000	0.0000	0.0000

Figure 49: NOIZEXEC output (summary of noise results, by directivity)

PRINT TOTAL NOISE SUMMATION : NOZOU3 NOIZEXEC EXECCASE TIME: 17:00:20 DATE: 1/15/92 UCAP --- NASA 4

UCAP FOR CR-2 INPUT -- R252INPT.DAT
 MX = 0.245, J = 1.46, TEMP = 56.2, P/PREF = .9627, VTIP = 434 FPS
 4XS CONFIGURATION, RUN 252.3 - 50/50 POWER SPLIT
 ***** FIRST ATTEMPT AT POWER MATCH *****
 FRONT BLADE ANGLE = 48.87 DEG. - MEASURED - CP MATCH = 48.87
 REAR BLADE ANGLE = 48.54 DEG. - MEASURED - CP MATCH = 48.54
 FRONT & REAR BLADES ASSUMED IDENTICAL

***** SUMMATION OF FRONT AND REAR NOISE HARMONICS *****
 RESULTS AT OBSERVER POSITION 1 : VISUAL COORDINATES RETARDED COORDINATES
 X POSITION ANGLE X POSITION ANGLE
 FRONT ROTOR : 4.82 56.49 6.34 43.90
 REAR ROTOR : 4.55 53.39 7.01 41.11

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF 1 TIMES BLADE PASSING FREQUENCY

RADIATION	FREQUENCY	DB	PHASE	P REAL	P IMAG	RMS PA
688.42		-45.8	0.0	0.0000	0.0000	0.0000
592.37		65.3	277.7	0.0492	-0.3642	0.3675
496.33		118.1	295.1	-14.6318	-0.8484	16.1518
400.29		-134.0	54.6	0.0000	0.0000	0.0000

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF 2 TIMES BLADE PASSING FREQUENCY

RADIATION	FREQUENCY	DB	PHASE	P REAL	P IMAG	RMS PA
1289.79		-78.3	391.3	0.0000	0.0000	0.0000
1184.75		62.3	58.8	0.0205	0.0163	0.0261
1088.70		159.3	248.2	-243.9211	-688.9448	655.9812
932.66		62.2	131.5	-0.0171	0.0193	0.0258
836.62		-123.0	243.6	0.0000	0.0000	0.0000

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF 3 TIMES BLADE PASSING FREQUENCY

RADIATION	FREQUENCY	DB	PHASE	P REAL	P IMAG	RMS PA
1875.16		-109.2	243.9	0.0000	0.0000	0.0000
1777.12		27.5	92.9	0.0000	0.0000	0.0000
1681.87		155.3	314.4	844.7412	-884.5437	1166.5649
1585.85		141.9	184.8	-247.1882	-26.1392	248.4789
1488.99		36.7	311.3	0.0009	-0.0018	0.0014
1392.94		-134.7	78.5	0.0000	0.0000	0.0000

CALCULATED NOISE FOR HARMONICS IN THE RANGE OF 4 TIMES BLADE PASSING FREQUENCY

RADIATION	FREQUENCY	DB	PHASE	P REAL	P IMAG	RMS PA
2465.53		-125.2	198.4	0.0070	0.0000	0.0000
2369.49		9.3	45.2	0.0000	0.0000	0.0001
2273.45		131.6	223.3	-55.8678	-51.8259	75.6194
2177.40		141.4	182.4	-50.1917	228.9375	234.3749
2081.36		136.7	30.5	117.7964	69.4187	136.7296
1985.32		11.7	133.9	-0.0001	0.0001	0.0001
1889.27		-152.6	278.6	0.0000	0.0000	0.0000

Figure 50:NOIZEXEC output (summary of noise results at each frequency)

```

PROGRAM QWMUGEN

REAL RWMU(20,20), IWMU(20,20)

INTEGER TYPE

C  #(@) THIS WILL CALCULATE QWMU FOR LSTPARMS 351 TO 550
C  TYPE IS 1 FOR SEARS LIFT RESPONSE FOR SINUSOIDAL GUST
C  IT IS ASSUMED THE FOLLOWING INFORMATION ARE KNOWN:
C  NCP      NUMBER OF CHORDWISE PANELS. LSTPARMS
C  NSM      NUMBER OF RADIAL STATIONS. LSTPARMS
C  BD       CHORD/DIAMETER RATIO AT NSM STATIONS (BLADEGEO)
C  ZAR      LOCATION OF THE RADIAL STATIONS (LSTPARMS 101-110)
C  J        ADVANCE RATIO

REAL J, BD(10), ZAR(10)

WRITE(*,*) ' ENTER ADVANCE RATIO '
READ(*,*) J

WRITE(*,*) ' ENTER NUMBER OF CHORDWISE PANELS '
READ(*,*) NCP

WRITE(*,*) ' ENTER NUMBER OF RADIAL STATIONS '
READ(*,*) NSM
WRITE(*,*) ' ENTER ',NSM,' RADIAL STATIONS--ASCENDING ORDER '
READ(*,*) (ZAR(I),I=1,NSM)
WRITE(*,*) ' ENTER ',NSM,' VALUES OF CHORD/DIAMETER '
READ(*,*) (BD(I),I=1,NSM)
WRITE(*,*) ' ENTER Q '
READ(*,*) Q
WRITE(*,*) ' ENTER GUST VELOCITY, DIVIDED BY ROTOR TIP SPEED '
READ(*,*) WZERO
DO N=1,NSM
  SIGMA=3.14159/J
  DO M=1,NCP
    XN=-0.5+(FLOAT(M)-0.5)/FLOAT(NCP)
    RWMU(M,N)=WZERO*COS(2.0*Q*BD(N)*XN/SIGMA)
    IWMU(M,N)=WZERO*SIN(2.0*Q*BD(N)*XN/SIGMA)
  ENDDO
ENDDO
WRITE(*,1010)351,((RWMU(M,N),IWMU(M,N),M=1,NCP),N=1,NSM)
1010 FORMAT(I3,(T5,6(F9.4,1X)))
STOP
END

```

Figure 51
Listing of sample program to generate QWMU vector for sinusoidal gust

```

C      @(#) CRPBLK.F 1.1.1@(#)
C      90/08/15
C      16:47:12

C      @(#) BLOCK DATA FOR COMMON/CRPP01/
C      PURPOSE:  BLOCK DATA FOR COMMON/CRPP01/
C      MODIFIED TO MAKE DEFAULT VALUE OF CRPTOL 0.01

      BLOCK DATA CRPBLK

C--BLOCK DATA FOR CRPPRM

C--COMMON BLOCK FOR CRPPARMS

      REAL AFTHRM,      COUNT,      CRPBUG,      CRPTOL,      FWDHRM,
      $      RATIO,      ROW,      SPACE,      SWITCH

C      COMMON/CRPP01/CRPBUG,      SWITCH,      SPACE,      COUNT,
      $      CRPTOL,      FWDHRM,      AFTHRM,      ROW,
      $      RATIO

C      CRPBUG:  DEBUG SWITCH.  0:  NO DEBUG PRINTOUT
C                                     1:  ECHO INPUT
C
C      SWITCH:  CRP/SRP SWITCH.  0:  SINGLE ROTATION (DEFAULT)
C                                     1:  COUNTER ROTATION
C
C      SPACE:  DISTANCE BETWEEN BLADE PITCH CHANGE AXES, DIVIDED BY
C      FRONT ROTOR DIAMETER.
C
C      RATIO:  REAR DIAMETER DIVIDED BY FORWARD DIAMETER
C
C      COUNT:  MAXIMUM NUMBER OF FRONT/REAR ITERATIONS.  DEFAULT IS 0,
C      WHICH IS ONE TRIP THROUGH.
C
C      CRPTOL:  MINIMUM VALUE OF THE CONVERGENCE MONITOR REQUIRED TO
C      START ANOTHER ITERATION.  IF THIS IS <= 0, IT WILL BE
C      SET TO 1.0E+4
C
C      ROW:  ROW SELECTOR SWITCH:  SET INTERNALLY ONLY!
C      <1.5:  FRONT ROW
C      >1.5:  REAR ROW
C
C      FWDHRM:  HIGHEST FORWARD ROW WAKE HARMONIC TO USE FOR EXCITATION
C      OF REAR ROTOR.  NOTE THAT THE FORWARD ROTOR WAKE IS
C      STEADY WHEN VIEWED FROM A POINT MOVING WITH THE FRONT
C      ROTOR.  THE HARMONICS ARE HARMONICS IN SPACE ONLY.
C      THOSE HARMONICS > 0 WILL APPEAR UNSTEADY TO THE REAR
C      ROTOR IN THE SAME WAY BUMPS ON A ROAD CAUSE TIME VARYING
C      FORCES ON AN AUTOMOBILE MOVING DOWN THE ROAD.
C
C      AFTHRM:  HIGHEST REAR ROW POTENTIAL FIELD HARMONIC TO USE FOR
C      EXCITATION OF THE FORWARD ROTOR.  NOTE THAT THE REAR
C      ROTOR POTENTIAL FIELD IS, LIKE THE WAKE, STEADY ONLY
C      WHEN VIEWED FROM A POINT MOVING WITH THE REAR ROTOR.  IT
C      IS ALSO NOT HOMOGENOUS.
C
C      DATA AFTHRM/0.0/, COUNT/0.0/, CRPBUG/1.0/,
      $      CRPTOL/1.0E-2/, FWDHRM/0.0/, SPACE/-1.0/,
      $      SWITCH/0.0/

C      END

```

Figure 52
Listing of CRPBLK with changed default value for CRP tolerance CRPTOL

(THIS PAGE INTENTIONALLY BLANK)

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE April 1993		3. REPORT TYPE AND DATES COVERED Final Contractor Report
4. TITLE AND SUBTITLE User's Manual for UCAP: Unified Counter-Rotation Aeroacoustics Program			5. FUNDING NUMBERS WU 535-03-10 C NAS3-24222 Task Order #10	
6. AUTHOR(S) E.M. Culver and C.J. McColgan				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Hamilton Standard Division United Technologies Corporation P.O. Box 1000 Windsor Locks, Connecticut 06096			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135-3191			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Project Manager, Bruce J. Clark, Propulsion Systems Division, NASA Lewis Research Center (216) 433-3952				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Unclassified-Unlimited Subject Category			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This is the user's manual for UCAP (Unified Counter-rotation Aeroacoustics Program), the counter-rotation derivative of the UAAP (Unified Aero-Acoustic Program). The purpose of this program is to predict steady and unsteady airloading on the blades and the noise produced by a counter-rotation Prop-Fan. The aerodynamic method is based on linear potential theory with corrections for non-linearity associated with axial flux induction, vortex lift on the blades, and rotor-to-rotor interference. The theory for acoustics and the theory for individual blade loading and wakes are derived in <i>Unified Aeroacoustics Analysis for High Speed Turboprop Aerodynamics and Noise</i> , Volume 1 (NASA CR-4329). This user's manual also includes a brief explanation of the theory used for the modelling of counter-rotation.				
14. SUBJECT TERMS Prop-Fan, High Speed Turboprop, Aerodynamics, Noise, Counter-Rotation, Vortex Lift, Unsteady Lift, Wakes			15. NUMBER OF PAGES 172	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT *	